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An Analysis of Weapon System Acquisition Schedules

Jeffrey A. Drezner, Giles K. Smith

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PREFACE

The time required to define and develop a new weapon system is an important element of the overall acquisition process. Programs that are unnecessarily lengthy tend to dilute the level of technological advancement represented by fielded forces, while highly accelerated programs incur added risks of unscheduled delays and potentially high rework costs. A recurring theme of defense critics is that most programs err on the side of being too lengthy and that policy reforms should be introduced to shorten the development cycle.

This study identifies the major factors controlling the pace of typical weapon acquisition programs and suggests reforms that may yield overall benefits through reduction of typical development time. Ten detailed case studies were performed during the study. A broader survey of acquisition program schedules and milestone dates is also summarized here and reported more fully in a companion report.[1]

This study was sponsored by the Office of the Under Secretary of Defense for Acquisition and was carried out in the Acquisition and Support Policy Program of the National Defense Research Institute, a federally funded research and development center supported by the Office of the Secretary of Defense and the Joint Chiefs of Staff.

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[1]M. B. Rothman, *Aerospace Weapon System Acquisition Milestones: A Database*, The RAND Corporation, N-2599-ACQ, October 1987.

SUMMARY

Critics of the defense acquisition process argue that the time it takes to design, develop, and produce weapon systems is not only excessive, but is continuing to increase. However, there has been scant evidence to support or refute these claims. The purpose of this research is to collect and analyze data relating to this issue.

OBJECTIVES AND APPROACH

The study has three basic objectives: to determine if in fact acquisition programs are actually getting longer, to identify and understand factors that affect program length, and to suggest ways to shorten the duration of acquisition programs.

We first collected schedule data on 107 aeronautical weapon systems over the past 40 years and then compared data on programs from different decades. To ensure consistent comparisons among programs, we identified three milestones for each system:

- Milestone I—start of the demonstration and validation phase
- Milestone II—beginning of full scale development (FSD)
- First delivery—delivery of the first operationally configured production article to the user.

Statistical tests were performed to measure any possible long-term trends. Also, since earlier studies had indicated that the length of Phase I (Milestone I to FSD start) had increased more rapidly than that of Phase II (FSD start to first delivery), we divided the sample into two groups and performed a statistical analysis of those data.

For the second objective, we conducted a detailed analysis of ten weapon systems, considering a wide range of potential factors affecting program duration and attempting to determine the degree of their effect.

CHRONOLOGICAL TRENDS

Results of the analysis show that, although there are large variations in the duration of programs in each decade, the time to design and develop programs has apparently lengthened. The programs we examined from the 1970s and 1980s took, on average, two years longer than those surveyed in the 1950s and 1960s. Specifically, both Phase I and Phase II took a year more to complete than had earlier programs.

Although programs do appear to be getting somewhat longer, the dominant observation that can be made by examining the time trends is the large variation in program duration, both across weapons of similar type and across any given time period. This variation has implications for attempts to shorten overall acquisition length.

FACTORS AFFECTING LENGTH

Determining whether program durations are increasing is considerably easier than determining *why* they increased. Having observed wide variability in program duration during any particular time period, we decided to explore a few programs in considerable detail. Our hope was that by investigating some programs in depth we would be able to identify and quantify those factors that influenced program duration.

To this end, we selected and examined ten programs for in-depth review that had Milestone I dates after 1970 and exhibited a wide variety of program characteristics, acquisition strategies, and schedule outcomes. We hoped that differences in program characteristics would help highlight the factors that influenced program duration. To represent program duration, we constructed the following model:

Actual Program Length = Length of Original Plan
+ Deviation from Plan

We examined the programs first to identify all the potential factors that we believed might be capable of influencing the original program schedule or any deviation from that plan. The factors we initially identified were

- Competition at the prime contractor level.
- Concurrency, meaning an overlap in time and effort between the development and production phases of a program.
- Funding adequacy during the planning phase.
- Existence of prototyping.
- Separate contracts for each phase of the program.
- Priority of the program to the service relative to other ongoing programs.
- External guidance such as OSD or Congressional direction, reviews, restrictions, and designations.
- Joint management with other agencies.
- Program complexity, or interactions with agencies external to the program.

- Technical difficulty.
- Concept stability, or stability in mission, operational concepts, and doctrine.
- Contractor performance.
- External events such as inflation, earthquakes, labor strikes, etc.
- Funding stability.
- Major requirements stability.
- Program manager turnover.

The first six affect the plan only, the next five may affect either the plan or subsequent slip, and the last five affect the slip only.

We then performed a second detailed review of each program, this time with the intention of determining the schedule effect of each specific factor on a program.

It was not possible to assess the reasonableness (validity, quality, etc.) of the *original plans*, except in terms of subsequent slip due to factors internal to the program, mainly because of a lack of documentation on the early planning phase, and the rationale behind it. An important result of this portion of the analysis is the observation that schedule estimates are not given the critical evaluation that cost estimates are given during the planning stages of a program. This includes both the Milestone I and Milestone II decision points.

We were able to associate all of the schedule slip in each program with specific factors. On average, the ten programs incurred slips of about one-third of the planned duration and one-fourth of the actual program length, or about two years. Many factors are responsible for this slip, although four appear to account for the largest portion of schedule slip in the ten programs we examined: external guidance, technical difficulty, funding stability, and external events. All but technical difficulty can be classified as external to the program, and funding stability and external guidance are controllable by either another DoD agency or by Congress. Removing the effects of the external factors reduces actual program length by about 11 percent, a fairly substantial amount. Further, most programs seem to conform well to their plans after removing the effects of these external factors. The exception to this appears to be the programs that were dominated by technical difficulty: JTIDS, AMRAAM, and LANTIRN.

The implication here is that providing improved program stability can reduce the program length by about 10 percent on average, or about one year. This means reducing external guidance to programs and providing and maintaining a more predictable funding environment. Reducing the effects of technical difficulty requires more careful analysis of technical risk and application of these results to schedule planning.

There is no single, narrowly focused policy option that would reduce the length of the acquisition cycle. Rather, coordination of several different initiatives involving the cooperation of both DoD agencies and Congress is necessary.

OTHER HYPOTHESES AND OBSERVATIONS

This research also attempted to identify relationships among several aspects of the problem. The following relationships were examined:

- The plan and subsequent deviation.
- Cost growth and schedule slip.
- Time spent in Phase I and program slip.

Although the factors affecting the plan show some interesting qualitative patterns, no strong association exists among the length of the plan, the factors affecting the plan, and the actual schedule outcome. It strongly suggests that programs with fairly short plans can, in some circumstances, have successful schedule outcomes.

Cost growth and schedule slip are often thought of in one of two ways: Either they occur together in a program, with one enhancing the other, or there is a tradeoff in the sense of incurring more of one to prevent the other. We found no evidence to support either contention.

Another commonly held belief is that time spent in Phase I, usually building and testing prototypes, will pay off in later phases of the program. We therefore expected to find that programs that spent proportionately more time in Phase I would incur less schedule slip. No such relationship was found.

Our inability to establish these relationships may be due in part to the small database available. Schedule analysis is characterized by a large number of factors with a potential effect on schedule, usually a small number of programs in the database used to test hypotheses, and a shortage of good documentation on the original plan. Increasing the database available to perform schedule analysis would be a valuable contribution. We believe that the framework developed in this research is a useful tool for that task.

ACKNOWLEDGMENTS

The authors wish to acknowledge the assistance provided by program managers and other senior staff members in the system program offices for the ten systems researched in detail. Of course, the use and interpretation of those data are the sole responsibility of the authors.

A special thanks are due RAND colleagues Susan A. Resetar and William C. Martel, who provided useful comments during their technical review of the draft report. Robert Brown provided useful suggestions on structure and organization. Also, special thanks go to Nancy Elwood for revising all the manuscripts.

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I. INTRODUCTION

The assertion that most acquisition programs take too long is a common theme in much of the analysis and criticism of the weapons acquisition process. The usual form of the argument is that bureaucratic processes introduce unnecessary delays in the acquisition cycle. Additionally, at least some of the critics claim that major weapon acquisition programs of the 1950s and 1960s were completed much more quickly than typical programs of today and that comparable programs in the commercial world are completed more quickly than their counterparts in the military. These comparisons are intended to buttress the assertion that today's weapon acquisition programs are unnecessarily lengthy.

The length of time required to develop and produce a weapon system is important for at least two reasons. One is that designs tend to be frozen early in the acquisition cycle, thus identifying the system with the level of technology that existed at that time. Any delays in translating that technology into operational weapons reduce the competitive edge our forces might obtain through use of advanced technology. A second consequence of delays is that longer programs tend to be more costly because of increased inflation and overhead, the potential for real material/labor price increases, and the opportunity to incorporate changes in the program. The Packard Commission, in their report on defense management, stated that the length of the acquisition cycle is "a central problem from which most other acquisition problems stem."[1]

Despite several studies that have addressed this issue directly, and many more that have touched on it to some degree, there is remarkably little consensus on the exact nature of the problem, its degree of severity, or possible solutions. This might seem puzzling because at first glance the schedule aspects of a program should be rather easily measured, so that at least we should be able to agree on how the schedules of modern programs compare with those of earlier decades and how the commercial and military worlds compare in this regard. However, even such basic issues are matters of contention.

The present study was undertaken to sharpen our understanding of the issues associated with measuring acquisition schedules, evaluating trends in program duration, and identifying the factors affecting that

[1] *A Quest for Excellence*, Final Report to the President by the President's Blue Ribbon Commission on Defense Management, June 1986 (The Packard Commission Report).

duration. The overall goal was to provide suggestions on how to shorten the time required to complete weapons acquisition programs.

BACKGROUND

The question of whether acquisition program duration can, or should, be shortened is an old one. To get some idea of the status of research on this topic, it is useful to review some of the major studies that have touched on issues relating to program duration.

In 1972 the Commission on Government Procurement argued that adoption of their recommendations "should also result in a net reduction in the time and cost to go from the statement of a need to the effective use of a system to meet it."[2] However, shortening the acquisition cycle was obviously not a major objective of the Commission, which made no attempt to show how their recommendations could shorten the length of the development cycle; and, in fact, many of their ideas (more careful assessment of need for a new system, testing of new technologies before incorporation in a development program, etc.) might be expected to lengthen the cycle.

Perhaps the first study to directly and substantively address the subject of acquisition cycle time was the Defense Science Board (DSB) 1977 summer study.[3] That study took the useful step of breaking the overall acquisition time into three parts:

1. Decision time, leading up to start of full scale development (FSD).
2. Development time, together with testing necessary to start production.
3. Production time.

First, they noted that the time required to perform the actual engineering development of weapon systems (from start of FSD to start of production) had not changed much over the past several decades, even though it might be argued that modern systems tend to be more complex than earlier ones. Next, they noted that the rate of production is largely affected by the rate at which money is available, and that budgets are affected by a complex set of political factors far exceeding the scope of acquisition policy. A subsequent study conducted by RAND provided further evidence supporting these conclusions.[4]

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[2]*Report of the Commission on Government Procurement, Volume 2*, 1972.

[3]*Report of the Acquisition Cycle Task Force*, Defense Science Board 1977 Summer Study, March 1978.

[4]G. K. Smith, and E. T. Friedmann, *An Analysis of Weapon System Acquisition Intervals, Past and Present*, The RAND Corporation, R-2605-DR&E/AF, November 1980.

That left the front-end decision time as a major focus of attention. The DSB study team concluded that the average duration of such decision time had increased from around two years during the 1950s to nearly five years in the early 1970s. They further concluded that an accumulation of organizations and management layers involved in such decisions was a major source of delays in decision time.

Subsequent attempts to further substantiate that conclusion were, however, not very successful. A 1979 study[5] found little evidence that OSD-level management review process (DSARC/DAB reviews)[6] was causing substantial delays in typical acquisition programs. Instead, they found that instability in funding, changes in system requirements, excessive testing, and insufficient concurrency between development and production seemed to be the major culprits in stretching the acquisition time.[7]

In 1982 the Air Force conducted a major study on how to shorten time and reduce cost of weapon acquisition.[8] That study concluded that for many kinds of systems the overall acquisition time had increased compared with programs in the 1950s and 1960s, and that much of the time increase had occurred in the pre-FSD phases and in production. Furthermore, the study reported that the factors affecting overall program duration had changed. Programs with FSD start before 1970 tended to be dominated by technical considerations, while post-1970 programs were dominated by problems of program instability. Major recommendations focused on improving funding stability as a way to reduce overall acquisition cost and to prevent stretchouts in production. No recommendations were made regarding ways to shorten the length of either the pre-FSD or the FSD phases.

In 1985 the Defense Science Board conducted a study on the process by which weapon system requirements and performance specifications are developed. One part of that study consisted of comparing military and commercial processes and experience in developing large, complex systems. Five commercial programs were examined. Although the

[5]W. G. Moeller, et al., *Accelerating the Decision Process in Major System Acquisition*, The Logistics Management Institute (LMI), September 1979.

[6]The Defense System Acquisition Review Council (DSARC), first organized in the early 1970s, renamed the Defense Acquisition Board (DAB).

[7]Most of those factors would be expected to affect the duration of the engineering development phase. But other studies, both before and after the LMI study, concluded that the engineering development phase had not changed much in duration over the past several decades.

[8]*The Affordable Acquisition Approach Study*, Hq. United States Air Force Systems Command, February 1983.

report[9] does not provide quantitative schedule information for any of the five programs, one of the conclusions was that commercial programs were generally more successful in reaching an appropriate balance of risk with cost and schedule goals and that great importance was generally attached to holding to schedule. The subsequent Packard Commission referred to this work in support of their conclusion that military program acquisition schedules should be shortened.

In 1986 the Analytic Sciences Corporation conducted a study[10] that attempted to devise an independent schedule assessment tool to apply to airframe development programs. A substantial database was assembled on about a dozen fighter aircraft programs, and a list of possible "schedule driver" parameters was identified, but no modeling of those parameters was attempted.

Somewhat more recently, the Institute for Defense Analyses (IDA) published two reports[11] describing an attempt to develop a "schedule assessment tool" for evaluating the schedule aspects of acquisition programs for proposed fighter and attack aircraft and for air-launched missiles. Those reports contain a considerable amount of data on the hardware and schedule aspects of nine tactical aircraft programs and 14 air-launched missile programs, thus substantially augmenting the relevant quantitative database. Further, the authors developed schedule estimating relationships for several intervals extending from start of pre-FSD activity (start of prototype, or issuance of request for proposal (RFP) for nonprototype programs) through a defined early production milestone. Although the results contain some implications for how to control program duration, at least for tactical aircraft and missile programs, the authors did not make recommendations on that topic.

The related issue of moving from development to production deserves mention as this transition has been recognized as problematic and as an important contributor to program duration. In 1983 the Defense Science Board conducted a study on the transition from development to production, with the objective "to develop recommendations to improve and accelerate the transition of weapons systems

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[9]*Practical Functional Performance Requirements*, Defense Science Board 1985 Summer Study, March 1986.

[10]Eric K. Nelson, *Independent Schedule Assessment FSD Study*, Analysis Science Corporation, Report TR-5300-2-2, June 1986.

[11]B. R. Harmon, L. M. Ward, and P. R. Palmer, *Assessing Acquisition Schedules for Tactical Aircraft*, Institute for Defense Analyses Paper P-2105, February 1989; and B. R. Harmon and L. M. Ward, *Methods for Assessing Acquisition Schedules of Air-Launched Missiles*, Institute for Defense Analyses Paper P-2274, November 1989.

into production."[12] The substance of the final report dealt almost entirely with measures designed to lower the risk of transition. Although risk reduction might translate into a time savings, the report did not address that aspect directly.

More recently the Congressional Budget Office (CBO) examined the degree of overlap between the final phases of development and the initial phases of production.[13] Such "concurrency" is frequently advocated as a way of shortening the time required to move into production. After examining the history of several programs with varying degrees of concurrency, the CBO concluded that "no strong relation exists between concurrency and schedule delay."

Several of the studies noted above had objectives that ranged far beyond the issues of program duration, and their conclusions are not always in full agreement. However, when one examines the portions of those studies that dealt with program schedules, particularly the analysis methodology and the underlying databases, a surprising consistency emerges in three areas important to the present study.

First, all of the reports revealed, either explicitly or implicitly, some serious methodological problems; and much of the work was not very analytically rigorous. Analysts do not always agree on which milestone should be used to define the starting or ending of a program. Some argue that a program "started" well before Milestone I, when serious concerns began to arise about the adequacy of the present force and the need for introduction of a new system. Others pick Milestone I as a start date, and still others argue that a program started with FSD authorization. Similar problems exist in identifying the ending point of a program. Some analysts use Initial Operational Capability (IOC) date, and others use delivery of the first production unit. The result is inconsistency in the schedule interval being analyzed, making it difficult to decide if the conclusions of one study agree with those of another study.

Another methodological problem is that not all programs are at a comparable level of maturity at a particular milestone. For example, one program might start FSD with little more preparation than a design study, while in another program that milestone might be preceded by fabrication and extensive testing of a full scale prototype. It might reasonably be expected that FSD for the former program would take longer than for the latter. Yet simple comparison of FSD

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[12] *Transition of Weapons Systems from Development to Production*, Defense Science Board, August 1983.

[13] *Concurrent Weapons Development and Production*, Congressional Budget Office, August 1988.

duration would generally not reveal the difference in program situations.

Many of the earlier studies considered only one independent parameter: the year, or decade, in which a program started. But we know that many factors affect the duration of an acquisition program, such as funding and requirements adequacy and stability, the level of technological advance, and unexpected technical difficulties. Program start date is not a very good proxy for that bundle of independent variables.

Most of the studies agreed that the time required for the actual engineering development of a system cannot be reduced very much in typical programs. There is also general agreement that perhaps the most powerful way to shorten the acquisition cycle (through production completion) would be through higher sustained production rates, but that the budget allocation decisions needed to sustain such high rates hinge on broad issues of force composition and development strategy that transcend the detailed issues of "efficient" acquisition procedures. That leaves the front end decision process (pre-FSD start) and the transition from development to production. Despite continuing interest in shortening the time required for those phases, progress remains elusive.

OVERVIEW

To effectively build on and extend the earlier work, we selected two research approaches. First, it seemed useful to conduct a more systematic and broad-ranging study on whether acquisition program durations are in fact getting longer over time. We therefore examined the schedule aspects of a wide range of aeronautical weapon systems acquired over the past 40 years. Data were collected on 46 aircraft, 15 helicopters, and 46 missiles, with program start dates (equivalent to DSARC/DAB Milestone I) ranging from the mid-1940s to the early 1980s. That work was limited to recording actual program durations, without much attempt to understand why they came out that way.

The results of this extended survey of program durations are discussed in Sec. II. Detailed documentation of the database is provided in an earlier report.[14]

Although an analysis of trends in program duration seemed likely to provide some useful insights, it would clearly not be a sufficient response to the question of how to reduce program durations. Thus, our second research approach was to examine several acquisition

[14]M. B. Rothman, *Aerospace Weapon System Acquisition Milestones: A Database*, The RAND Corporation, N-2599-ACQ, October 1987.

programs in enough detail that we could identify and understand the factors affecting their durations. We expected that if a sufficiently rich set of factors could be identified, and their individual effects on program duration could be quantified, that might provide a basis for suggesting strategies for reducing the duration of typical future programs.

Details of the procedure used to examine factors affecting program duration are described in Sec. III and results shown in Sec. IV.

Overall conclusions and recommendations from the study are discussed in Sec. V. Brief case histories of the systems studied in some detail are contained in appendixes.

II. TRENDS IN ACQUISITION DURATIONS

Whether program durations are increasing is not, by itself, conclusive evidence that modern practices are better or worse than those of yesteryear. However, some knowledge of those trends could reasonably be expected to yield useful insights into the broader issues of acquisition management. We prepared a database of schedule information on a wide range of aeronautical weapon systems acquired over the past 40 years. Data were collected on 46 aircraft, 15 helicopters, and 46 missiles, with program start dates (equivalent to DSARC/DAB Milestone I) ranging from the mid-1940s to the mid-1980s. That survey is fully reported in a companion document.[1] Results are summarized here for the convenience of the reader.

MILESTONE DEFINITIONS

To facilitate consistent comparison of programs conducted during different time periods and under different management systems, we identified three milestone dates for each system:[2]

- Milestone I, the start of the demonstration and validation phase. This marks the beginning of the period where contractor(s) and the service management office prepare designs and perform hardware testing in preparation for full scale development;
- Milestone II, the beginning of full scale development.
- Delivery of the first operationally configured production article to the user (as distinct from delivery of test articles to the development agency).

Milestone I is the most difficult date to define consistently over time. For programs that started after 1970 the formal DSARC/DAB Milestone I date is used. For older systems we chose the start of the design or study efforts connected with a single cohesive weapon system (rather than component technology development or concept studies). Because of the need for such judgment calls, the duration of the period between Milestones I and II is subject to greater uncertainty than that

[1]Rothman, 1987.

[2]The same definitions used here apply to the case studies used in the analysis of factors affecting program duration, discussed in Secs. III and IV of this report.

of the subsequent phases. Even so, we believe the results are sufficiently precise to permit useful comparisons.

TOTAL PROGRAM DURATIONS

Are programs really getting longer than they use to be? An overview of that question is shown in Fig. 1, which displays the program duration from Milestone I to first delivery of an operational unit for 51 systems where both start date and initial delivery date were available.[3] The systems that define the extremes of the figure are labeled.

The dominant impression from this set of data is that in every time period a large program-to-program variation existed in the length of the acquisition period, even for programs of similar type. *Program start date is obviously not an adequate proxy for the factors that affect program duration.*

Despite the large scatter in the data, we performed several statistical tests to measure any possible long-term trends. A simple linear fit yields a slope of almost exactly one month increase in average program duration for each successive year of program start. While the variance is quite large (an adjusted R^2 of 10 percent), the hypothesis of zero slope is rejected at the 2 percent confidence level. Thus there is some evidence that the duration of typical programs has been increasing.

Earlier studies had suggested that the duration of Phase I had been increasing more rapidly than that of Phase II. We therefore examined each of those phases separately.

Phase I Durations

When examining the individual phases of acquisition, we used a different statistical approach, dividing the overall sample into two groups and testing to determine if the two groups do indeed represent different populations. Because the formal Concept Validation phase was introduced in about 1970, we divided the sample into pre-1970 and post-1970 groups. We deleted the pre-1950 programs on the basis that they no longer represented modern system designs.

By focusing on a smaller portion of the program duration, we were able to increase our sample size to 31 programs that started in the

[3]Either program start date or first delivery date was unavailable for the 56 programs not included in Fig. 1. This figure is slightly different from the corresponding one in Rothman (1987), which had a one-year error in delivery date for the AH-64 and erroneously included the SH-60B as a new system. Correcting those errors has little effect on the conclusions regarding possible long-term trends in program duration.

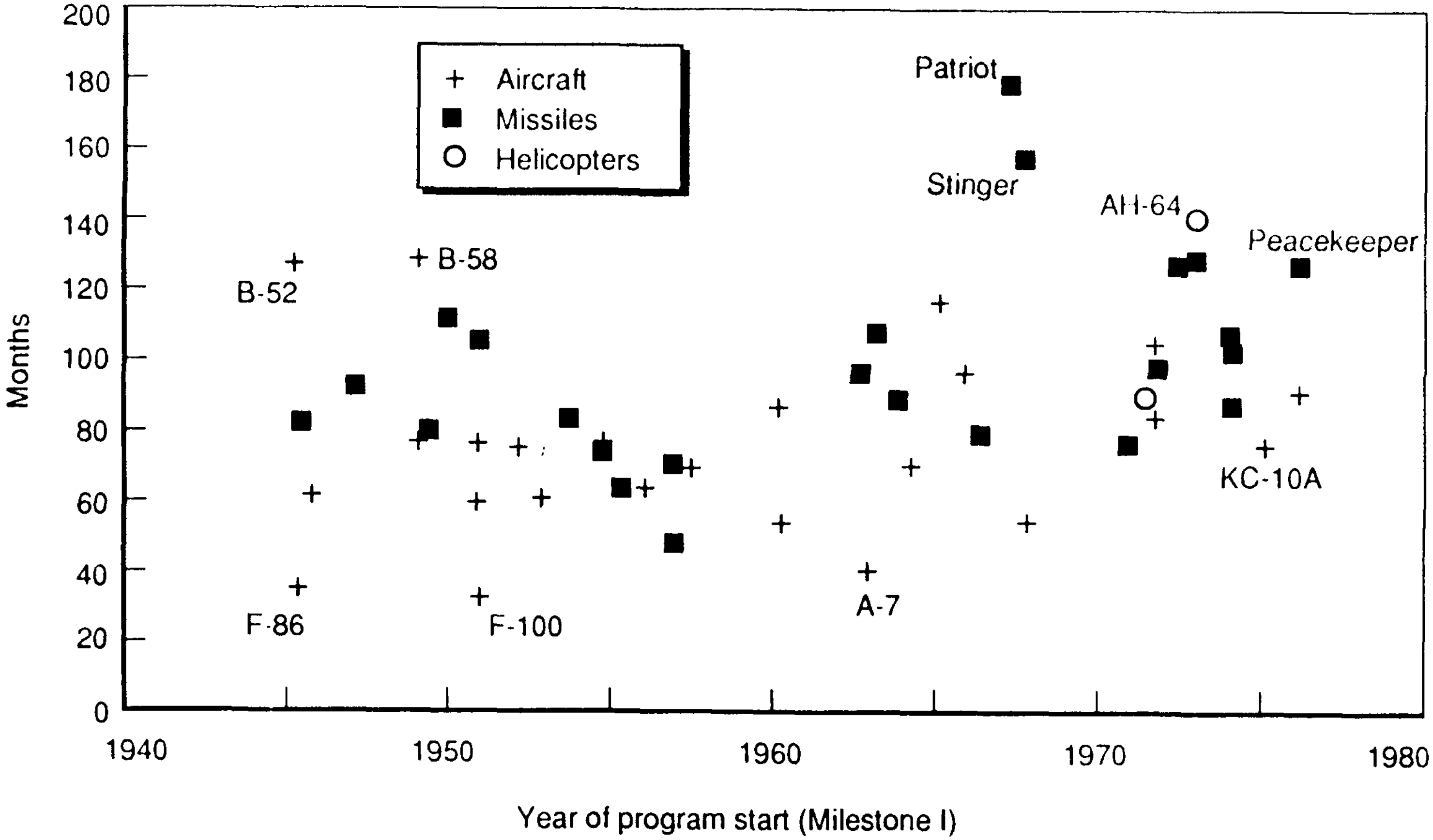

Fig. 1—Time from Milestone I to first operational delivery

1950–1969 time period and 26 that started in 1970 or later.[4] The distribution of Phase I durations for programs in those two time periods is shown in Fig. 2. The height of each bar represents the number of programs with a particular Phase I length. The block in each case covers the central 50 percent of the distribution. The mean value of the post-1970 sample is nearly a year longer than that of the pre-1970 sample, and a statistical test indicated that the two samples were indeed from different populations, at the 1 percent confidence level.[5]

Phase II Durations

A similar examination of Phase II (FSD plus whatever testing and initial production are necessary to reach first delivery of an operational unit) led to surprising results (Fig. 3).[6] Again, the mean value of the post-1970 sample is a year longer than that of the earlier sample, and a test of means indicates that they are indeed different, but only at a 5 percent confidence level (rather than the 1 percent confidence level in the two groups of Phase I results noted above). This finding is in contrast to previous studies showing that Phase II, or FSD, has not appreciably lengthened.[7]

ASSESSMENT

This survey of overall program durations leads to two conclusions:

1. There is some evidence that recent programs typically take longer than programs conducted some time ago. In particular, programs conducted during the 1970s and 1980s appear to have taken, on average, an extra year in Phase I and an extra year in Phase II, compared with programs of the 1950s and 1960s.

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[4]Two new programs were added to the sample from Rothman (1987): the small intercontinental ballistic missile (SICBM) (Milestone I in December 1983, Phase I duration of 36 months) and the advanced antitank weapon system (AAWS-M) (Milestone I in April 1986, Phase I duration of 38 months).

[5]Tested using the Mann-Whitney U test.

[6]The Phase I and Phase II samples differ in two ways. First, the samples are different because information was available in only one phase for some programs. Second, the pre-1970 distinction is based on the date when the phase started. This leads to three programs being in the pre-1970 portion of the Phase I sample and the post-1970 portion of the Phase II sample: F-15, Patriot, and Stinger. This categorization scheme is based on the hypothesis, partially supported in this analysis, that the acquisition environment at the time a program enters a phase in large part characterizes that phase. In other words, Phase I and Phase II can be treated independently.

[7]See for instance *Report of the Acquisition Cycle Task Force*. Defense Science Board 1977 Summer Study, March 1978; Smith and Friedmann, 1980.

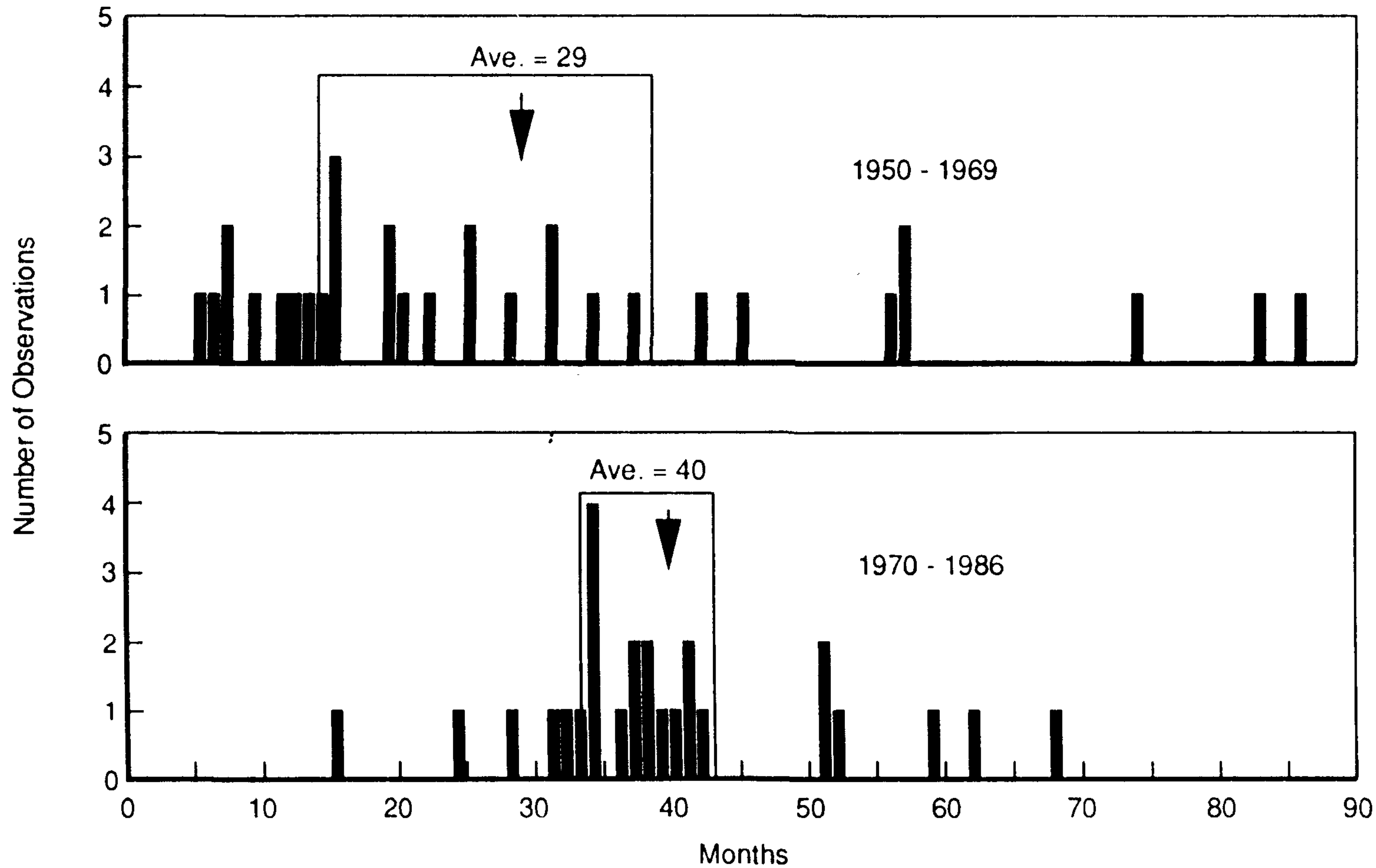

Fig. 2—Distribution of Phase I durations

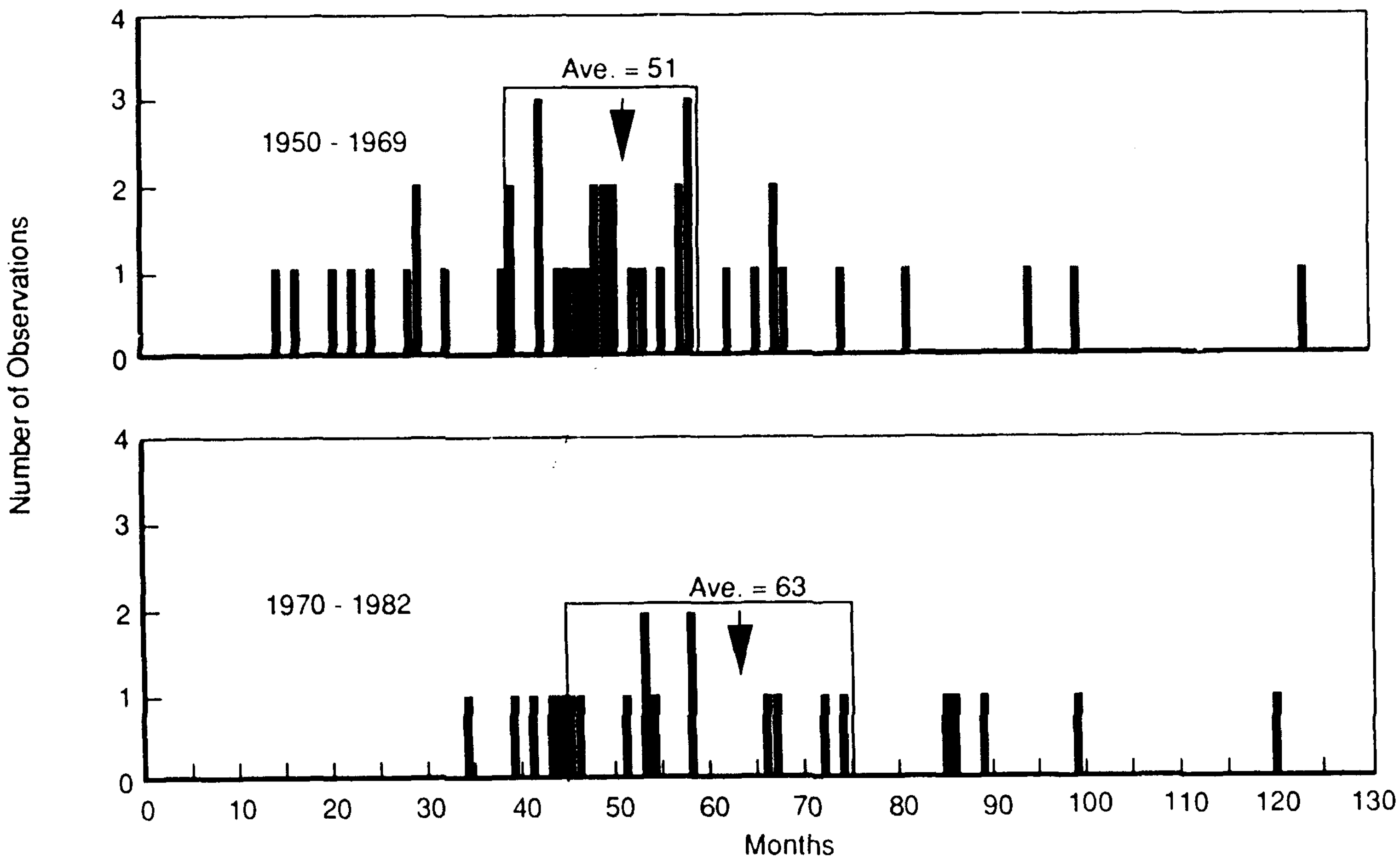

Fig. 3—Distribution of Phase II durations

2. In each of the four decades covered in this survey there was a large program-to-program variation in acquisition duration. Program start date alone appears to tell us very little about *why* programs are getting longer.

III. FACTORS AFFECTING PROGRAM DURATION

Having observed the wide variability in duration within particular time periods, we decided to examine a few programs in considerable detail. By using consistent schedule measures across weapon system programs, quantifying a wider range of explanatory variables, and focusing on the decision process in the program planning stage, we hoped to provide less ambiguous results than previous studies.

RESEARCH OBJECTIVES AND APPROACH

We had two basic objectives in this part of the study:

- Identify the factors affecting the duration of weapon system acquisition programs and determine the relative importance of these factors.
- Suggest ways to mitigate the adverse effects of these factors on program length and thereby shorten the acquisition cycle.

The first objective involves quantifying the effects of distinct factors on program duration, and the second objective examines policy options and strategies available to DoD to shorten the acquisition cycle.

We decided to examine about a dozen programs in considerable detail, rather than a large sample in less detail. This would allow a much better understanding of the factors that drive acquisition pace in at least those programs we examined and permit us to resolve some of the methodological problems that have hindered previous analyses of acquisition schedule. This approach does limit the generalizability of our results somewhat, but we can still cover enough programs to generalize at an aggregate level. Further, if this approach proves to be useful, then the database can be expanded in the future.

In particular, our approach allows us to be somewhat more consistent in measuring program length. As noted earlier, previous studies have tended to emphasize the middle of the acquisition cycle, from the start of FSD to IOC, omitting the earliest planning stages and the final production phase. Omission of the production phase seems justified because it is so clearly defined by funding availability. There is ample evidence that production stretchouts are mainly due to budget constraints, rather than technical difficulties or other factors.[1] The earlier planning phases, before the start of FSD, justify more attention in this kind of analysis, if only because critics and some past studies have cited this phase of acquisition as the source of unnecessary delays. Unfortunately, the earlier one goes in the history of a weapon system, the fainter the trail becomes. System concepts evolve, names change, personnel move around, and documentation tends to get destroyed.

We decided to address our analysis to the period from Milestone I to first operational delivery. Most programs have a reasonably well-defined Milestone I, indicated by a formal DSARC (now DAB) meeting, or other documentation that defines formal program initiation. First operational delivery is better defined than IOC, which varies across programs in terms of timing and maturity of delivered systems. Although we do exclude some potentially important parts of the acquisition cycle, early concept exploration and low rate production, we believe that our definition of program length adequately captures those phases we are most interested in:

- Phase I, from Milestone I to FSD start, during which the weapon system configuration is defined and the subsequent development program is planned, and
- Phase II, from FSD start to first operational delivery, which covers full scale engineering and developmental testing activities.

First operational delivery marks the end of intensive FSD and the beginning of the transition to the production phase. These definitions allow some reasonably quantitative analysis.

The earlier phases (before Milestone I) of the acquisition cycle remain a source of interest but are not included in the present study. It is plausible that funding availability strongly affects the duration of pre-Milestone I work, as it does the duration of the production phase. Concept formulation studies on a wide range of candidate systems are conducted more or less continually, and at each budget cycle advocates attempt to move their programs ahead to a more formally acknowledged and fully funded position. During the past couple of decades Milestone I has apparently been a major "gate" in this process, with approval granted only to those systems that seemed likely to find room in subsequent budgets for full development and production.

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[1]Congressional Budget Office, *Effects of Weapons Procurement Stretch-Outs on Costs and Schedules*, November 1987.

MODEL AND HYPOTHESES

Our basic approach, and an important distinction from previous studies, is characterized by the model we adopted to represent program duration:

Actual Program Length = Length of Plan + Deviation from Plan

This model makes explicit our analytical framework: The actual length of a weapon system program is a combination of its *planned* schedule and any *deviation* from that basic plan. We adopted this model because the plan itself seems likely to affect program duration, independently of the other factors. For example, if a program is originally designed with an unreasonably tight schedule, the disruptions caused by recovering from problems might be much worse than if a more realistic schedule had been planned. Likewise, an artificially extended plan obviously affects duration. This model is also useful because it highlights what is perhaps the most prominent and easy-to-measure aspect of program length: the schedule "slip" or difference between the planned and actual duration.

Our research hypothesizes that distinct factors affecting a program's schedule are reasonably identifiable and that their effect on either the plan or the deviation can be quantified, thus allowing determination of their relative importance in affecting schedule outcomes. We expected to see some pattern in the factors affecting schedule outcomes, with some factors consistently having a greater effect on outcomes across all the programs in our sample than others. From a policy point of view, we hope that at least some of these factors can be controlled by DoD agencies or other actors in the acquisition system, thus allowing a potential for accelerating the acquisition cycle.

The model also makes explicit some of our additional hypotheses. One concerns the relationship between the plan and the deviation from the plan. The basic notion here is that program schedule outcomes depend not only on both the plan and its execution, but on any relationship between them. For example, short programs need short plans and good execution. A more specific hypothesis derived from the model is that a reasonable plan will include a relatively long Phase I (time from Milestone I to FSD start) compared with Phase II (time from FSD start to first operational delivery), thus reducing subsequent schedule slip because of the lessons learned during Phase I hardware-related activities.

Another hypothesis is that different sets of factors affect the plan and the deviation from the plan and therefore suggest different opportunities for accelerating the acquisition cycle. The available alternatives for shortening the cycle may differ. For instance, if the length of the original plan is in fact strongly related to the actual schedule outcome, then focusing on ways to formulate shorter, but still reasonable (e.g., "good") plans would perhaps offer more scope for accelerating acquisition than the more common emphasis on preventing schedule slip. Similarly, a plan that accounts for the factors affecting schedule slip might increase the probability of good execution and therefore a more successful schedule outcome. This is different from the more common approach that formulates a plan as if execution would not be a problem and then reacts to the inevitable problems that arise in the course of development.

In summary, the model provides an appropriate conceptual framework for three areas of interest:

- What is the relative contribution to actual schedule outcomes between the plan and deviation?
- Is a different set of factors associated with different types of plans and schedule outcomes?
- What do these differences suggest in terms of effective policy options for shortening the acquisition cycle?

SAMPLE SELECTION

Since we intentionally limited the number of programs included in our analysis, we recognized that the particular ones we examine would be critical to the success of the analysis. We therefore had two main criteria for selecting programs to examine. First, we limited our sample to programs with Milestone I dates after 1970, because we wanted programs that fell under recent initiatives to streamline or accelerate the acquisition cycle. Examining post-1970 programs also makes conclusions drawn from the analysis more relevant to the current environment. Second, we wanted a wide variety of program characteristics, acquisition strategies, and schedule outcomes; and we wanted both long and short programs, at least one program from each service, and both major systems and subsystems. We believed that these differences in program characteristics would help us identify and compare the more important factors affecting program duration.

Based on these criteria and suggestions from acquisition executives in all three services, we originally selected the 13 programs shown in Fig. 4, which categorizes the programs as to whether the original plan was shorter or longer than the average, and by whether the program suffered some schedule slip. Two programs, the Navy's Unmanned Air Vehicle and the Airborne Self-protection Jammer, had such incomplete

Planned schedule	Actual schedule	
	As planned	Extended
Shorter than average	Army : MLRS ~~Navy : UAV~~ Navy : F-18 Air Force : A-10	Army : DIVAD ~~Navy : ASPJ~~ Air Force : LANTIRN Joint : AMRAAM
Longer than average		Army : M-1 Army : AH-64 ~~Navy : LAMPS~~ Joint : JTIDS Joint : GPS

Fig. 4—Schedule matrix

information that we have not yet included them in the analysis. We also eliminated LAMPS because we were unable to find any documentation on the original plan. The final research included the remaining ten programs.

When we initially selected programs to examine in detail, we had intended that each box in Fig. 4 contain at least one program. As we gained a better understanding of the programs in our sample, an interesting result emerged: None of the programs that had longer than average plans achieved those plans.

FACTOR IDENTIFICATION AND QUANTIFICATION

Using such official program documentation as *Decision Coordinating Papers*, *Program Management Directives*, *Acquisition Plans*, program review briefings, and *Selected Acquisition Reports*, supplemented by interviews with program office personnel and public literature, we identified the original plan and any subsequent program schedule changes. Dates for Milestone I (program initiation), Milestone II (start of full scale development), and first operational delivery were collected in a time series format and so provide the evolution of the program schedule. Using these data, we calculated the length of the intervals of interest in our study: Phase I is the time (in months) from Milestone I to FSD start, Phase II is the time from FSD start to first operational delivery, and total program length is the sum of these. These data sources also were used to identify the factors affecting the length of the original plan and deviations from the plan.

Ideally, we would like to develop a schedule estimating relationship so that, given projected values for the various factors affecting program duration, we could estimate the length of a program. By identifying the major schedule drivers, such a relationship would enable planners to direct attention toward the most important ways to change the schedule.

Despite some effort along those lines,[2] only moderate progress has been made in developing a relationship of factors affecting schedule. What is clear is that program durations are affected by several parameters, some of which are inherently difficult to quantify. For example, programs differ considerably in the degree of technical advance sought and in their overall complexity and consequent engineering and management challenge. To date no one has defined useful metrics for measuring even such obvious factors. Furthermore, programs are affected by many external influences, including available budget, service priorities, and even the personal preferences of senior executives. Those are inherently difficult to identify and to quantify.

Two fundamental characteristics of schedule analysis constrain research in this area. One is that original schedule plans are not documented in terms of justification for the proposed schedule. This is a serious limitation because the analyst has only very limited insight into why the actual program deviated from the plan. Was it because some aspect of the program (e.g., technical difficulty) was not properly reflected in the plan, or because some external constraint overrode "normal" schedule planning, or because the scope of work changed during the course of planning. Our ability to deduce lessons on how to improve the accuracy of schedule predictions or how to organize acquisition programs that could be accomplished in a shorter time is seriously constrained by the lack of insight into the basis for the original plan. An analogy would be the plight of the cost analyst having to work only with the original estimate of total cost, without any information on the constituent elements of that estimate.

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[2]Harmon, Ward, and Palmer, 1989; Harmon and Ward, 1989.

A second troublesome characteristic of schedule analysis alluded to earlier is that many factors can be expected to affect program duration, whereas the number of programs in any data sample is small. Meaningful statistical analysis to correlate independent and dependent parameters is therefore impossible. Of course, a similar problem plagues the cost analyst, but he has at least one independent variable that has a strong intuitive and logical link with cost: total vehicle weight. There appears to be no such clearly definable and quantitative parameter that can be used to conduct schedule analysis.[3]

As a result of these inherent limitations, schedule analysis must be performed in a generally heuristic manner. Detailed examination of specific programs appears to be the most appropriate way to get real insight into the factors affecting program duration. To minimize the consequences of such basic methodological problems, we examined each program in detail to determine (1) the major factors that had affected the formulation of the original program schedule and (2) the factors that led to any subsequent slips in that schedule. For each program we listed all identifiable and distinct events during the course of program planning and execution with the potential to affect the schedule. We then categorized these events into the 16 broad groups of factors shown in Table 1. Six of these factors affect the plan only, five affect the deviation only, and five factors may affect both the plan and the deviation. We do not suggest that this list is complete; it reflects only those factors we could identify in program documentation for the programs in our sample. Brief definitions of each factor are given below, along with an indication of the theoretically most probable direction of effect.

Factors Potentially Affecting Original Plan

Competition. Program had a competition element at the prime contractor level at one or more stages in the process with particular goals. The plan would be affected by including a competitive phase, tending to result in longer schedules.

Concurrency. Refers to an overlap in time and effort between the development and production phases of a program. Concurrency would be expected to shorten a program schedule.

Funding Adequacy. Whether the program was planned in an environment of adequate funding to meet the specified program objectives and milestones. Adequate funding implies a smoother program but perhaps a little longer than a program planned around insufficient

[3]Work performed by IDA has found some correlation between certain elements of schedule and certain aspects of system weight, but weight remains a much less useful parameter than in cost analysis.

Table 1

FACTORS AFFECTING PACE IN SAMPLE

Factor	Original Plan	Deviation from Plan
Competition	X	
Concurrency	X	
Funding adequacy	X	
Prototype phase	X	
Separate contracting	X	
Service priority	X	
External guidance	X	X
Joint management	X	X
Program complexity	X	X
Technical difficulty	X	X
Concept stability	X	X
Contractor performance		X
External event		X
Funding stability		X
Major requirements stability		X
Program manager turnover		X

funds. Inadequate funds might imply a plan that increases risks by cutting some needed testing, etc. Highly related to service priority.

Prototype Phase. Program had a prototype phase at a certain stage of the process with particular goals. Including a prototype phase would be expected to increase the planned length of the program, though not necessarily the actual program length.

Separate Contracting. There were separate contracts, varying in type and scope, for each phase of the program, rather than total package contracting. This might tend to increase the length of the original plan.

Service Priority. A measure of how important the program was relative to other services in a joint program or relative to other programs in a service. The issue of "selling" a program to either OSD or Congress is important here. A high priority program may have a short planned schedule to give the impression that everything is under control and risks are minimal. Conversely, a low priority program might be stretched out to protect higher priority programs. This measure is highly related to funding adequacy.

Factors Potentially Affecting Plan and Deviation

External Guidance. This factor includes "program guidance" (guidance that conflicts with normal acquisition procedures, or is unrealistic or unachievable), "reviews" (oversight and audits by Congress, Congressional agencies, OSD, and the services), "restrictions and designations" (statements in Appropriation and Authorization Acts limiting and/or conditioning action by the program office), and other types of administrative or bureaucratic delay (compliance with legislation, directives and instructions, decision delays, etc.). These are specific to each program with large variations in type and potential severity. With the exception of direction to accelerate, external guidance would commonly increase the plan and cause deviation. Acceleration would cause a shortening of the plan.

Joint Management. Whether the program was conducted under a joint management structure and, if so, the number of agencies involved. Conventional wisdom holds that such programs take longer than single-service programs.

Program Complexity. A measure of the management and administrative complexity of the program. Includes interrelatedness and interactions with external programs. Programs with many interactions with other programs might have longer plans and potentially be subject to schedule slip.

Technical Difficulty. This includes both technical complexity and problems resulting from technical issues. Technically complex programs would commonly have longer plans and have greater than average potential to incur schedule slip due to technological risk.

Concept Stability (System Specification). A measure of the maturity of the weapon system concept in terms of the stated mission. Includes changes to system specification (design) and operational concept. Also includes the relative "newness" of the design, concept of operations, or technology. This factor would tend to increase both planned and actual program durations.

Factors Potentially Affecting Program Deviation

Contractor Performance. A measure of nonperformance by the contractor, uninfluenced by DoD or external events. Includes late deliveries of parts or subsystems by subcontractors to the prime, poor workmanship, and unpreparedness or lack of capability by the prime. Would tend to cause schedule slips.

External Event. Refers to an event external to the program office or DoD that had some effect on the program. The event was unanticipated, uninfluenced by DoD, and uncontrollable by DoD. Includes acts of God, and unexpected cost growth due to inflation. Would tend to cause schedule slips.

Funding Stability. Budget changed (increase or decrease) as a result of service, OSD, or Congressional action. Both absolute amount and percent of change are relevant. Would tend to cause program stretchouts and/or increased risk.

Major Requirements Stability. Increase or decrease in the specified capabilities of the system or in the quantities to be produced. Increasing requirements tends to lengthen program duration, while reducing requirements may shorten the program.

Program Manager Turnover. Frequency of program manager changes and length of duty. Changes in program management would tend to cause decision delays due to management continuity problems and possibly a rebaselining of the schedule.

Most of these factors are fairly straightforward. The only factors we have not found in earlier studies are concept stability and program complexity.

Using these definitions, we then performed a second detailed review of each program, this time attempting to associate a specific factor with a specific schedule effect. Since the original program plan was often not well recorded or rationalized in program documentation, we deduced, in retrospect, what factors might logically have affected the formulation of the original program schedule, given the available documentation and what we know of the acquisition environment at the time a program was in the planning stage. Factors affecting schedule slip were usually identifiable, albeit with some ambiguity in a few cases. In fact, we were able to account for all the deviation in nine of the ten programs.[4]

The results of the data collection on original plan and schedule slips were also displayed in a detailed graphical form to simplify understanding of the sometimes quite complex shifting of the various program events. An example for the Apache helicopter program is given in Fig. 5, which shows the time history for seven program milestones and events. The originally scheduled date shown in the program plan as of Milestone I is indicated by the intersection of each event line with the horizontal axis (measured in terms of months after Milestone I). The vertical axis indicates the date of events that affected the program schedule. If the originally planned date was achieved (as was the case

[4]The exception is JTIDS, documented in App. G. Of the 90 months of schedule slip incurred by JTIDS, we were able to attribute only 39 months to specific factors. The other 51 months remain unknown. In the analysis that follows, we have dropped JTIDS from our database when this large amount of unknown slip can bias the results.

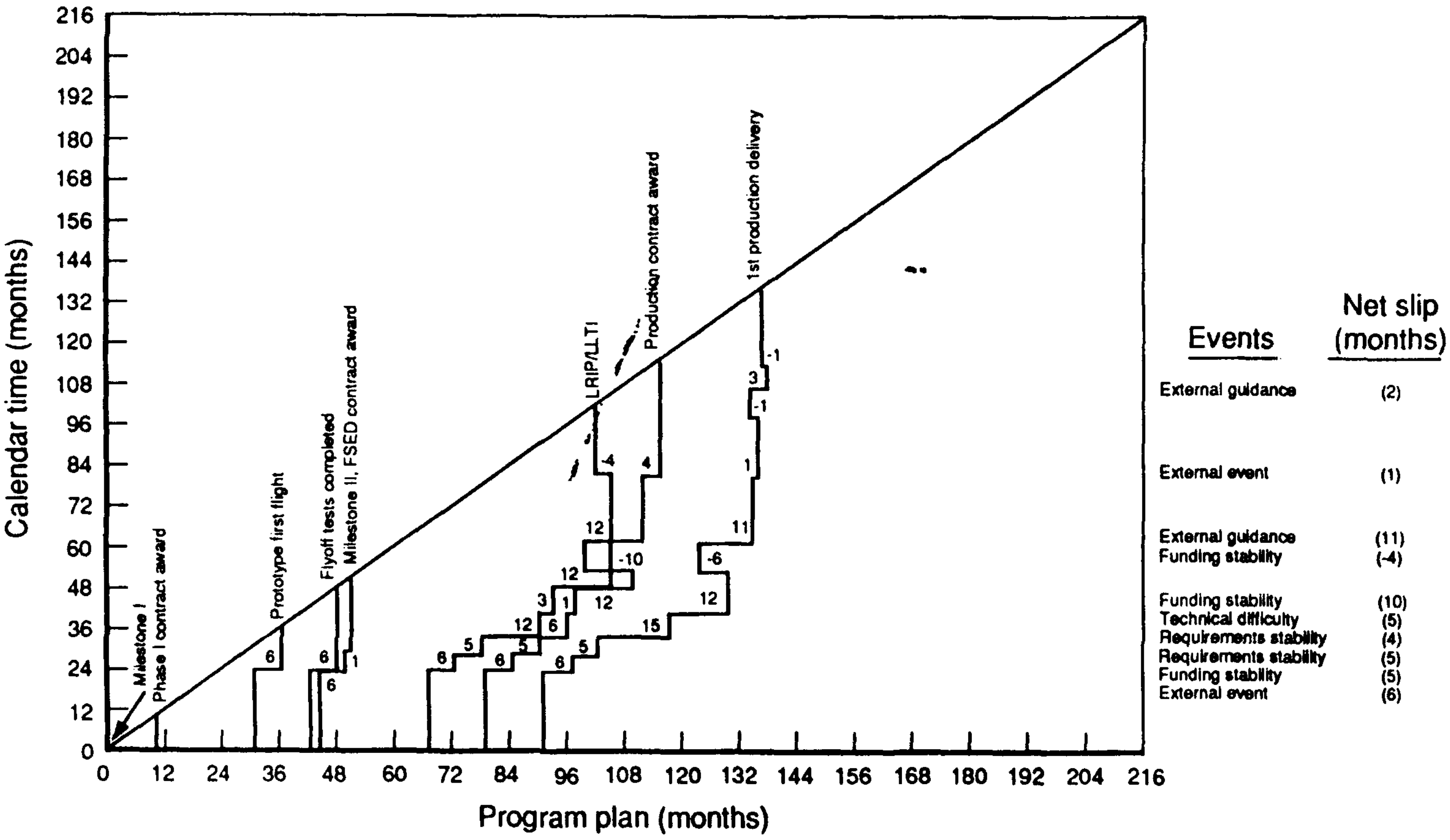

Fig. 5—Apache helicopter program schedule evolution

for Phase I contract award for the Apache), then the line moves vertically to an intersection with the 45-degree line. Any subsequent slip in achievement date is represented by a horizontal jog in the event line, and the actual achievement date is indicated by the intersection of the event line with the 45-degree line. The duration of each slip and (to the extent possible) the predominant cause of each slip affecting first operational delivery are noted on the figure.[5]

In some cases, slips in interim milestones were reflected in subsequent milestones, while in other cases they were not. We have not yet been able to account for this phenomenon, except to observe that the effect of a slip in any one milestone on other aspects of the program's schedule seems to be determined by the flexibility and dependency of the milestones.

The 16 factors that constitute the basis of this analysis are not independent of each other and in fact are often highly interactive. The result is a "chicken and egg" problem when one is trying to match factors with effects on either the plan or the slip. Statistical modeling of the resulting database is infeasible. There are too many explanatory variables for the number of observations in our sample and poor or nonexistent quantitative data on the effect of each variable on the plan. Instead, in the analysis that follows, we rely on graphical presentation of the data and simple correlations when feasible, to understand the factors affecting the original plan or the deviation and patterns, trends, and relationships among variables.

[5] See App. D for a more complete description of the causes of each schedule slip in this example case.

IV. ANALYSIS RESULTS

GENERAL RESULTS

The basic data we collected are presented in Table 2, which shows the Milestone I (or equivalent) dates for each program and the planned and actual dates for FSD start and first operational delivery. We believe that these dates are functionally equivalent across these ten programs.[1]

Figure 6 shows the planned and actual program durations for the ten programs in our sample.[2] The program plans varied from 56 months for the LANTIRN program to 136 months for GPS, with an average of about 83 months. Of this, Phase I averaged 33.5 months and Phase II averaged 49.1 months, respectively 41 percent and 59 percent of the total planned schedule. The actual schedule outcomes of the programs also had high variation, ranging from 67 months for the MLRS and A-10 programs to 204 months for JTIDS, or an average of about 110

Table 2

PROGRAM MILESTONES

Program	Milestone I	FSD Start		1st Delivery	
		Plan	Actual	Plan	Actual
MLRS	Jan 77	May 80	Apr 80	Feb 82	Aug 82
A-10	Apr 70	Jan 73	Jan 73	Nov 75	Nov 75
DIVAD	Feb 77	Nov 77	Jan 78	Jun 82	Mar 84
M-1	Nov 72	Jun 76	Nov 76	Oct 79	Feb 80
AH-64	Sep 72	May 76	Dec 76	Apr 80	Jan 84
F/A-18	Apr 74	Aug 75	Dec 75	May 80	May 80
LANTIRN	Dec 79	Mar 80	Sep 80	Aug 84	Jul 88
AMRAAM	Nov 78	Dec 81	Dec 81	Aug 85	Sep 88
GPS	Dec 73	Mar 78	Jun 79	Apr 85	May 87
JTIDS	Sep 74	Aug 79	Jan 81	Mar 84	Sep 91

[1]By functionally equivalent, we mean that essentially the same activities were being performed across the programs at these dates. More detail on each program and the rationale behind our selection of specific dates are provided in the appendixes.

[2]These data are presented in tabular format in appendix Table A.1.

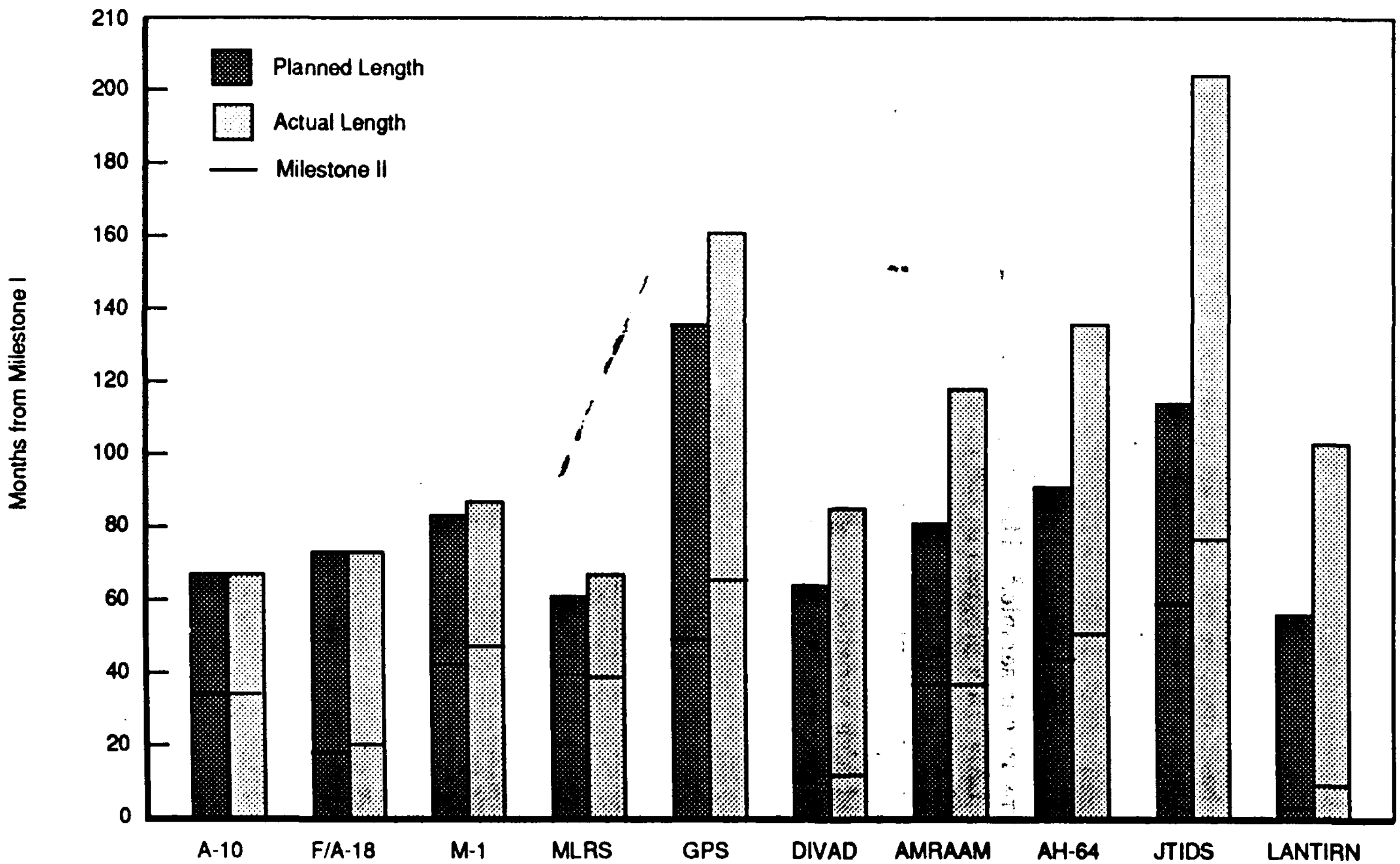

Fig. 6—Program durations

months. Phase I was 35 percent of the actual program length, and Phase II was 65 percent.[3]

Some interesting observations emerge from examination of Fig. 6. First, several of the programs had major schedule deviations, particularly the AH-64, LANTIRN, and JTIDS programs. Except for DIVAD, F/A-18, and LANTIRN, Phase I was intended to be almost half of the total planned schedule, an observation consistent with our belief that a good plan allows adequate time for preliminary hardware development and testing during the demonstration/validation phase of acquisition. Also note that although some slip occurred during Phase I, the vast majority was incurred during Phase II. However, in the F/A-18 case, for example, the Phase I slip was nullified by an accelerated Phase II, resulting in no schedule deviation when measuring the time to first operational delivery.

In general, our sample displays the basic characteristics we believed were necessary to identify the factors affecting acquisition pace. We have both short and long plans, some of which succeeded in meeting their first operational delivery date and some of which did not. Programs from each service are included, including three joint programs for which the Air Force acted as lead agency; and many of the programs fall under identifiable acquisition reforms. For instance, DIVAD was one of the first programs to be implemented under the streamlining initiatives of the late 1970s, while the A-10 was one of the first programs to include a distinct prototyping phase under then Deputy Secretary of Defense Packard's 1970 prototyping initiative. The remainder of this section documents the results of our attempt to determine if any of these program and system characteristics made a difference in the schedule outcomes of these programs.

ORIGINAL PLAN

Of the 11 factors that we identified earlier as having a potential effect on the original plan (see Table 1), effects of nine were actually identified.[4] Although the available documentation was not adequate to quantify the effect of each factor on the plan, it was sufficient to infer

[3]Note that JTIDS is something of an outlier in terms of its actual schedule outcome. If JTIDS is removed from the database, then the average planned and actual program lengths are 79 and 100 months, respectively.

[4]Technical difficulty and concept stability, previously identified as potentially affecting the length of the original plan, are not shown in Table 3. We could find no evidence of their influence when we examined each program in detail.

the direction. Table 3 shows that each of the nine factors made the plan either longer or shorter.[5]

Table 3 shows a few notable patterns. Incorporating a distinct competitive prototyping phase into the original plan tends to lengthen the plan, relative to not including such a phase, because of the time necessary for testing and evaluating the prototypes. Although a prototype phase may lengthen the plan, it does not necessarily add to the actual program length. The lessons learned during the prototype phase can often provide a more technically firm basis for entry into FSD and thus a smoother FSD phase from a technical difficulty point of view. Concurrency and providing adequate funding tend to shorten the plan by allowing certain activities to be conducted simultaneously and permitting more realistic planning, respectively.

An analysis of these factors' effects on the original plan can be complicated as many factors can work in both directions. The lack of concurrency can lengthen a plan, and the lack of separate contracting can shorten it. External guidance can affect the planned length in either direction, depending on what the guidance was. In the case of the A-10, the guidance was to prototype, thus necessitating additional time. In the case of the MLRS, both Congress and the Army wanted to field the system as soon as possible to meet a perceived critical shortfall in capabilities, so an accelerated strategy was approved.

In practice, many of these factors are closely related, for instance competition and prototyping, and the lack of concurrency and separate contracting. However, one can determine the dominant factor for a particular program and the effect of each factor by observing the timing of the events associated with a particular factor. For instance, the direction to accelerate the MLRS came before the original plan was formalized, and this caused the prototyping to be handled in a way somewhat different from the norm. Many of the activities usually associated with the FSD phase were performed during the prototyping phase. For the A-10, however, the external guidance was to include a distinct prototyping phase but still retain the standard FSD phase.[6]

Although each program is unique in terms of the factors that affect it and their specific effect on the program plan, careful consideration of such issues as funding adequacy, prototyping, and contracting strategy can allow decisionmakers to get a rough feel for how reasonable a proposed program plan is, based on historical precedent and changes in the acquisition environment.

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[5]The basis for these determinations is provided in appendix Table A.2.

[6]The case studies of each program in the appendixes provide the information necessary for these determinations.

Table 3

EFFECT OF FACTORS ON ORIGINAL PLAN IN SAMPLE[a]

Factor	MLRS	A-10	F/A-18	DIVAD	M-1	LANTIRN	AMRAAM	AH-64	GPS	JTIDS
Competition	L	L		L	L		L	L		
Concurrency	S	S	S	S	S	S	S	L		
Funding adequacy			S					S		
Prototype phase	L	L		L	L		L	L		
Separate contracting	S					S	S	L		L
Service priority				S	S	S	S	S	L	S
External guidance	S	L	S	S	S	S	S			L
Joint management							L		L	L
Program complexity									L	L
Rank by actual length	1	2	3	4	5	6	7	8	9	10
Rank by plan length	2	4	5	3	7	1	6	8	10	9

Key: Rank
1 - Shortest
10 - Longest

Direction of effect
S - Shorter
L - Longer

[a]Because a factor is not indicated as affecting a particular program it should not be interpreted to mean that the factor had no influence. Rather, in those cases, no evidence of effect was found. This was the case with funding adequacy, for instance.

An important observation of this portion of the analysis is that schedule estimates are not given the critical evaluation that cost estimates are given during the planning stages of a program. This includes both the Milestone I and FSD start decision points. Poor documentation on the rationale behind the decisions that went into the original plan, at both the program and DSARC/DAB levels, supports this contention. Further, there is no institutional advocate for schedule realism within DoD. In contrast, the Cost Analysis Improvement Group scrutinizes cost estimates at major milestones using a variety of well developed tools.

DEVIATION FROM THE PLAN

Deviation from the plan, or schedule slip, was measured as the difference between the length of the original plan and the actual time to first operational delivery. Of the ten factors shown in Table 1 with the potential to affect schedule slip, we quantitatively identified the effects of eight.[7] Table 4 provides the effects of these factors on the schedule outcome of the individual programs. The range of schedule slip varied from no slip in the A-10 and F/A-18 programs to 90 months of slip in JTIDS. The average slip across all ten programs was 27.5 months, or 33 percent of the average plan length and 25 percent of the average actual program length. Two programs incurred fairly minor slips (M-1 and MLRS), and the other six programs incurred slips ranging from 18 percent in GPS to a maximum in the LANTIRN program with 84 percent slip as a percentage of its original plan. These averages are heavily weighted by those programs with larger slips: AH-64, AMRAAM, LANTIRN, and JTIDS. We successfully accounted for all the schedule slip in nine of the ten programs; 51 months of slip in the JTIDS program remain that we could not associate with any particular factor because of data problems.[8]

The bottom two rows in Table 4 present the ranking of both the planned program length and the actual schedule outcome. With the exception of LANTIRN, the ranking did not change very much, indicating that the relative length of the plan is a reasonable indicator of the actual program duration for this set of programs.

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[7]The two factors not included here are program manager turnover and joint management. We found no indication of primary effect on schedule slip due to these two factors.

[8]The events and months of slip associated with each factor, and the time period in which it occurred, are provided in appendix Table A.3.

Table 4

EFFECT OF FACTORS ON SCHEDULE DEVIATION
(Net months of slip)

Factor	MLRS	A-10	F/A-18	DIVAD	M-1	LANTIRN	AMRAAM	AH-64	GPS	JTIDS
Contractor performance	1			6						
Funding stability				15		12	5	11	3	
External event	5							7	4	5
Technical difficulty						31	29	5	5	12
External guidance					4		3	13	13	29
Concept stability						4				
Major requirements stability								9		–12
Program complexity										5
Slip accounted for	6			21	4	47	37	45	25	39
Unknown	0			0	0	0	0	0	0	51
Total slip	6	0	0	21	4	47	37	45	25	90
Rank by actual length	1	2	3	4	5	6	7	8	9	10
Rank by plan length	2	4	5	3	7	1	6	8	10	9

Key: Ranking
1 – Shortest
10 – Longest

However, there does not appear to be a strong relationship between the length of the plan and the magnitude of subsequent slip. Using the sample average of 83 months planned schedule, five of the programs were shorter than average, and three of these (A-10, MLRS, and F/A-18) essentially achieved their schedule objectives. The other five programs were longer than average and only one (M-1) achieved a schedule outcome close to its goal. The variation in the magnitude of schedule slip can not be explained by the plan alone, implying that factors other than planned schedule length contribute substantially to schedule slip and the resulting actual program duration.

One can determine the relative importance of these factors in contributing to schedule deviation by taking the proportion of slip attributable to a given factor in each program. Figure 7 presents the results of this exercise for our sample, excluding JTIDS.[9] External guidance, technical difficulties, funding stability, and external events account for most of the schedule slip for the programs in our sample. Technical difficulties and external events are not necessarily controllable by any DoD agency or other actor, while funding stability and external guidance are potentially controllable. These last two factors account for 26 percent and 18 percent respectively of the schedule slip in the programs in which they occurred.

INTERNAL vs. EXTERNAL

As stated earlier, one of the more important goals of this research is to suggest ways to accelerate the acquisition process by mitigating factors that adversely affect program duration. One approach to this lies in understanding what the potential time reduction would be if factors that are potentially controllable by one or more actors in the process are in fact controlled. We can represent this in the current database by removing the effects of these "controllable" factors.

Perhaps the most interesting distinction is whether the factor is internal to the program (because of the way the program was originally set up or actions of program office and contractor personnel) or derives from the external environment and is therefore unrelated to the original program structure and uncontrollable by program office and contractor personnel. Table 5 shows the results of this type of analysis. External factors include funding stability, external guidance, major requirements stability, and external events. With the exception of

[9]It seems inappropriate to include JTIDS in this part of the analysis since the causes of 57 percent of its slip are unknown. However, including JTIDS does not change the general results.

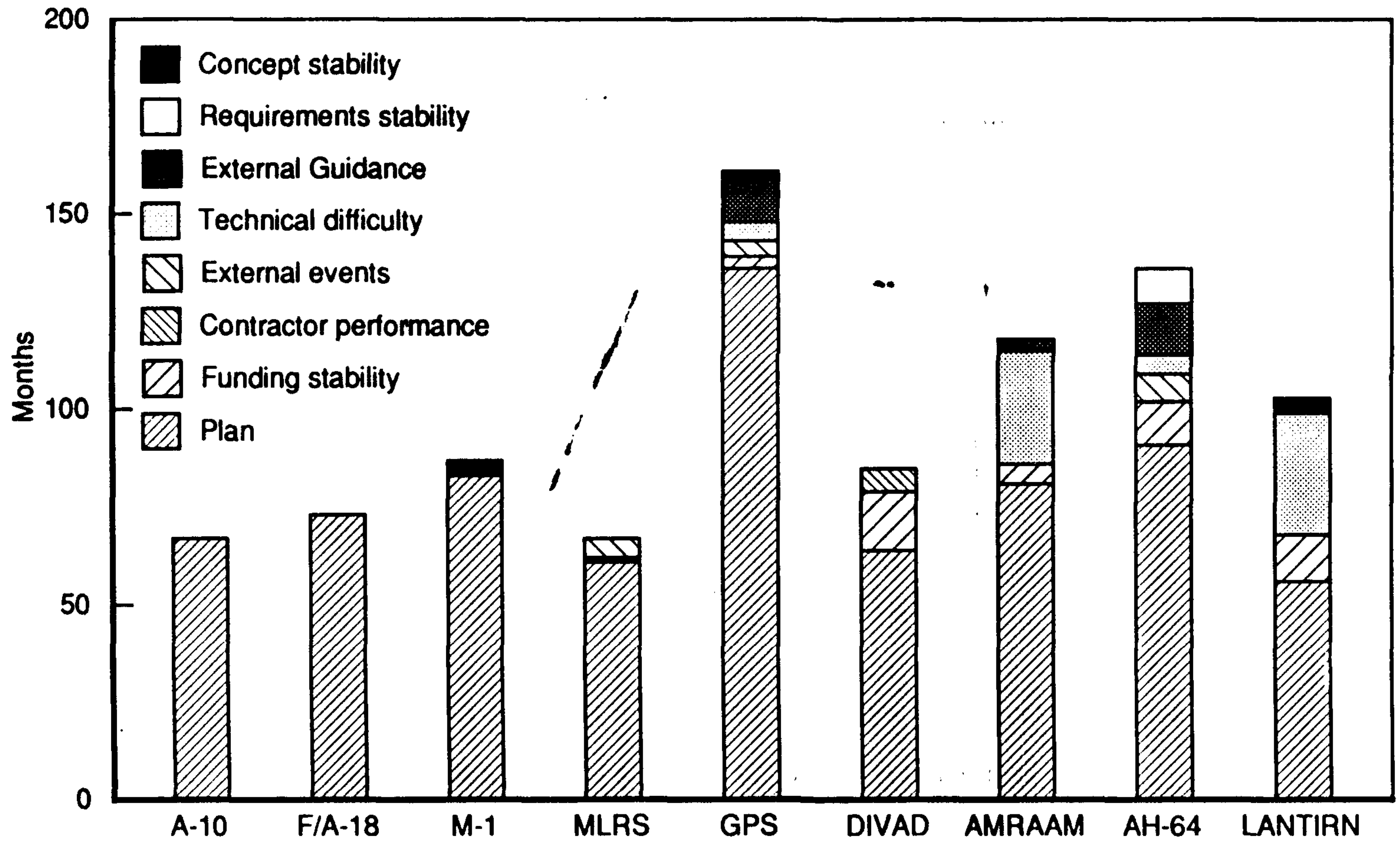

Fig. 7—Relative importance of factors affecting schedule deviation

Table 5

EFFECT OF EXTERNAL FACTORS ON PROGRAM DURATION[a]

	MLRS	A-10	F/A-18	DIVAD	M-1	LANTIRN	AMRAAM	AH-64	GPS	JTIDS
Planned length	61	67	73	64	83	56	81	91	136	114
Actual length	67	67	73	85	87	103	118	136	161	204
Total slip	6	0	0	21	4	47	37	45	25	90[b]
Internal	1	0	0	6	0	35	29	5	5	68
External	5	0	0	15	4	12	8	40	20	22
% Internal	16.7	0	0	28.6	0	74.5	78.4	11.1	20.0	75.6
% External	83.4	0	0	71.4	100.0	25.5	21.6	88.9	80.0	24.4
Slip as percent of plan										
Total	9.8	0.0	0.0	32.8	4.8	83.9	45.7	49.4	18.4	78.9
Internal	1.6	0.0	0.0	9.4	0.0	62.5	35.8	5.5	3.7	59.6
External	8.2	0.0	0.0	24.4	4.8	21.4	9.9	43.9	14.7	19.3
Potential reduction										
Adjusted length (mo.)	62	67	73	70	83	91	110	96	141	182
% of actual length	7.5	0	0	17.6	4.6	11.6	6.8	29.4	12.4	10.8

[a]External factors, those not in the control of the program office, include funding stability, external guidance, requirements stability, and external events.

[b]JTIDS data include the 51 months of slip unattributable to any factors. If this is excluded, then JTIDS experienced 31 months of attributable slip, 22 months (56.4 percent) due to external factors.

external events, these are in fact potentially controllable by either a DoD agency or Congress. The reduction in slip after removing the effects of these external factors ranges from 22 percent in AMRAAM to 100 percent in the M-1. In general, the remaining slip (due to internal factors) represents a substantial reduction from the total slip as a percent of the plan.

The average reduction in actual program length is 10 percent (see last row in Table 5), with a maximum of 30 percent in the AH-64 program (again excluding JTIDS). As Fig. 8 shows, the adjusted program length is a considerable reduction from actual time, averaging about 12 months. *After we eliminated external factors, most programs conformed quite well to their original plans.* The exceptions are those programs dominated by unscheduled technical development work: AMRAAM, LANTIRN, and JTIDS. One lesson here is that attempts to conduct short programs incorporating a high degree of technical advance, as in the case of AMRAAM and LANTIRN, are unlikely to succeed. In our sample, programs with these characteristics did not benefit much from excluding external factors because they are dominated by technical difficulties.

PATTERNS AND RELATIONSHIPS

Besides identifying the factors that affect acquisition pace, we also wanted to identify any patterns and relationships in the data between these factors and/or the components of actual program length: the original plan and deviation from the plan. Very few strong relationships emerged from our analysis. In general, the data are characterized by a high variability in factors and outcomes.

Many of the factors affecting the original plan—including prototyping, competition, concurrency, and the lack of separate contracting—are interrelated, often occurring in sets. The effect of these sets of factors tends to be consistent. Prototyping and competition affect the program plan in the same direction. Hardware testing and evaluation of competitive results require longer plans. Concurrency often implies the lack of separate contracting, thus shortening a plan by removing any need to allow for review and decisionmaking between phases.

The factors affecting schedule deviation do not seem to be correlated with each other, or with the factors affecting the plan. The factors affecting schedule slip tend to be a function of the unique system characteristics and specific environment surrounding a program. However, some patterns emerge even with this variability. Technical difficulties usually result from the level of technical advance sought and

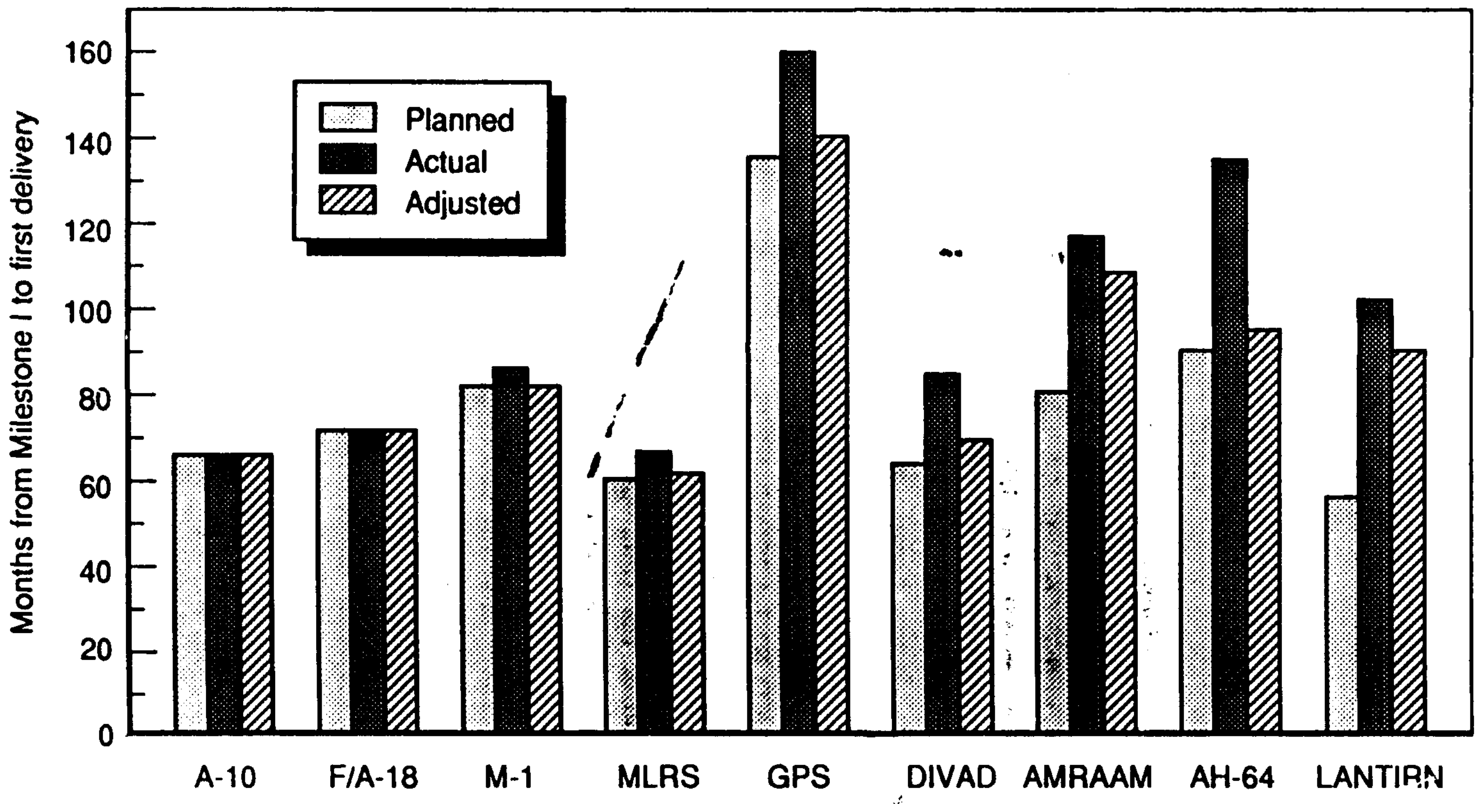

Fig. 8—Effect of external factors

often lead to substantial schedule slip, particularly in programs with short plans. External guidance tends to cause slips as well: With the exception of rare cases when requirements are relaxed or guidance is to accelerate (and it is backed with additional funds and streamlined decisionmaking), the factors affecting schedule deviation tend to cause delays in first operational delivery, rather than schedule improvements. In other words, unlike the factors affecting the plan, the factors affecting deviation tend to cause longer actual schedules.

As stated earlier, the model we adopted as a conceptual framework for our analysis—actual program length equals the sum of the planned length and deviation from the plan—makes explicit one of our underlying hypotheses: that the length of the original plan would be associated with the amount of deviation from the plan. For instance, a short plan should incur more deviation than a longer plan. Figure 9 plots the deviation and the length of the original plan. There appears to be no correlation here, with some planned short programs attaining that goal, while others did not. These data do not support the hypothesis that planned short programs are more likely to slip. A similar result is

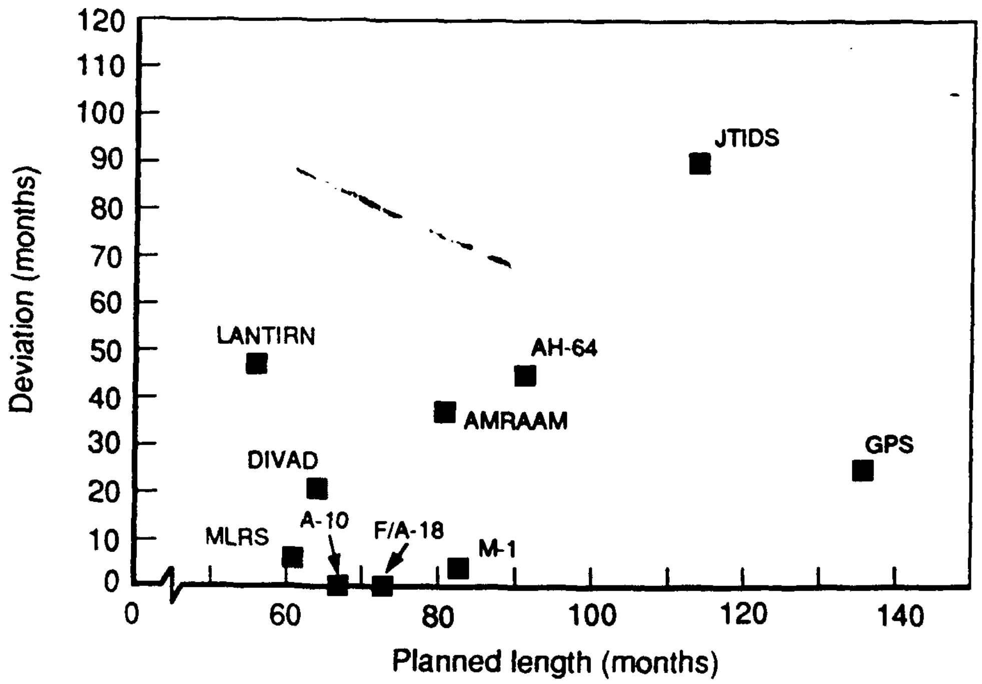

Fig. 9—Relationship between plan and slip

obtained when the external factors are removed from the program deviation. Figure 10 illustrates that there is no correlation between this adjusted schedule slip and the length of the original plan. However, the figure does illustrate two observations mentioned earlier: Most programs conformed quite well to their plans if external factors are removed, and the remaining programs (AMRAAM, LANTIRN, and JTIDS) are those dominated by technical difficulty.

An additional hypothesis was that time spent in Phase I was time well spent. Front end development work, particularly prototyping, would provide a firmer basis for entry into FSD. We found no evidence to support the notion that programs with a longer Phase I have smaller schedule deviations. In fact, there seems to be no relationship between prototyping and schedule slip across the ten programs in our sample: AMRAAM and AH-64 had longer plans and a prototyping phase, yet incurred substantially more slip than either the A-10 or the MLRS (both of which had prototypes) and about as much as LANTIRN (which had no prototype). The lesson here is that execution of

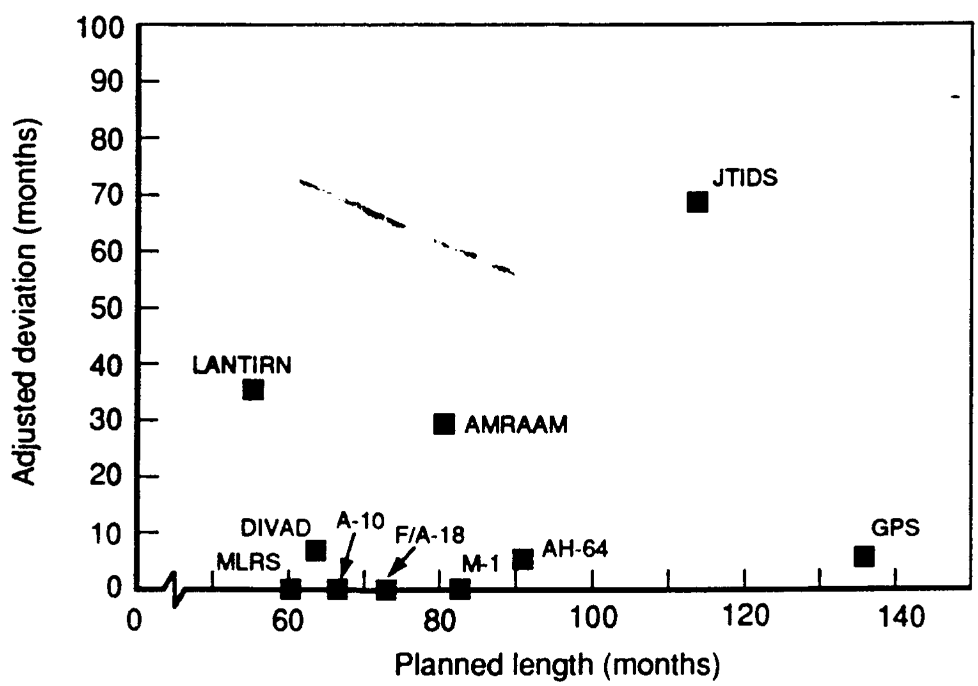

Fig. 10—Plan and "controllable" deviation

the plan is as important as the plan itself, and therefore execution issues should be considered during formulation of the plan.

Figure 11 plots the ratio of time spent in Phase I to time spent in Phase II against the slip as a percentage of the original plan. The ratio is a measure of the effort spent in Phase I. The variability in the ratio suggests that the distribution of work between Phase I and Phase II is not consistent across programs. The implication is that when formulating a program plan, we need to consider both phases together and tradeoffs made between them. We recognize, however, that one potentially confounding variable here is funding adequacy. Often, programs are planned with a short Phase I because funds are not available early in a program.

Past studies have asserted that schedule slip and cost growth are strongly related. One might expect to see either of two effects: programs with high cost growth and small schedule slips, indicating a tradeoff between incurring extra costs or added time, or high cost growth and large schedule slips, indicating a "problem" program. Neither of these assertions can be supported with these data, as Fig. 12

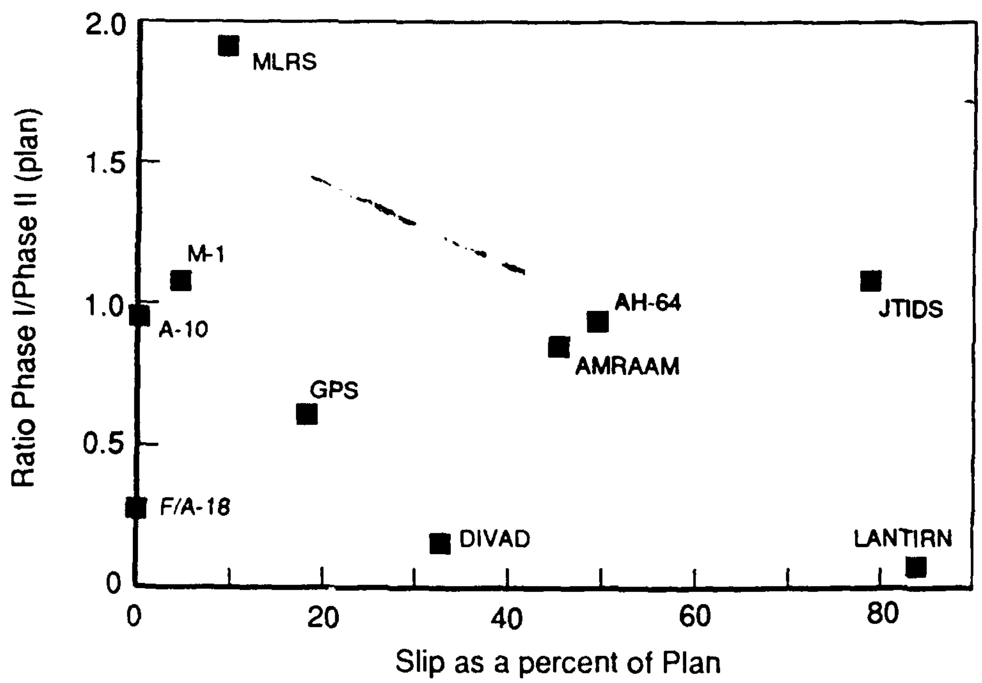

Fig. 11—Effect of time spent in Phase I

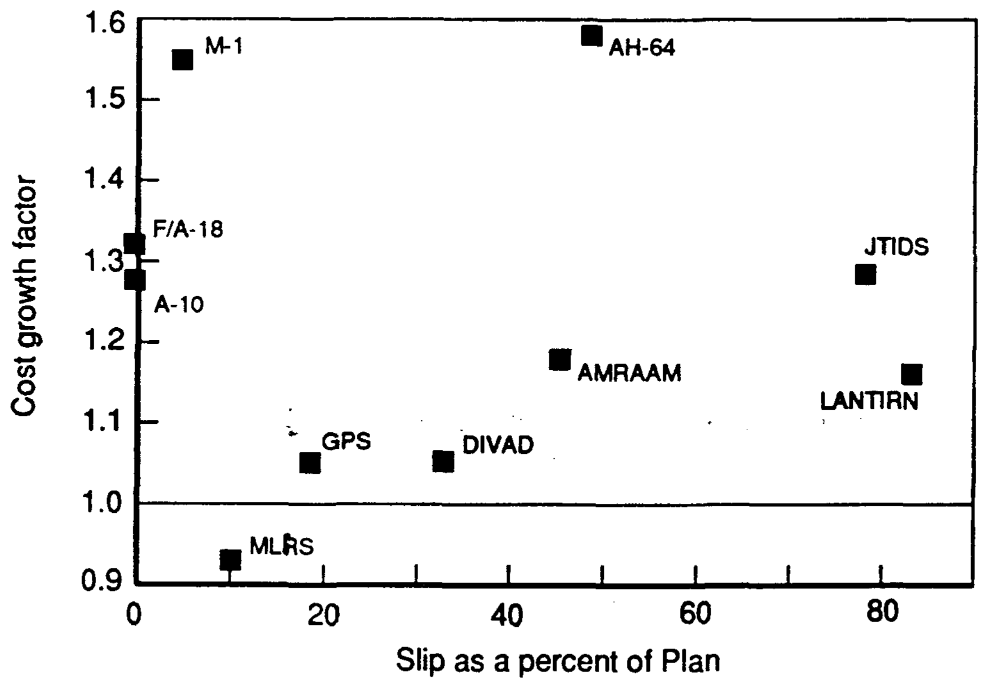

Fig. 12—Cost growth and schedule deviation

shows. A plot of cost growth versus schedule slip shows very high variability.[10] Despite conventional wisdom, cost growth and schedule slip appear to be unrelated to each other.

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[10]Cost growth is defined here as the ratio of the current estimate to the development estimate, in program base year dollars, as shown in the December 1988 *Selected Acquisition Report* for each program. We adjusted the current estimate by removing the effects of cost variance due to quantity and normalized along a cost-quantity curve to development estimate quantity. The factor shown in Fig. 12 is equal to the normalized current estimate over the development estimate. A ratio greater than one indicates cost growth.

V. CONCLUSIONS AND RECOMMENDATIONS

The length of the acquisition cycle is important for several reasons. Weapon system designs and associated technology tend to be frozen at the start of FSD. A longer program will result in the new system reaching operating units somewhat later, with the possibility that the technology incorporated in the system may not meet the current threat, or may have a shorter life because the threat changes. An overly lengthy program can cost more than a shorter program, all other things being equal, in large part because of the inflation and overhead allocation, and the opportunity to change requirements. Programs that incur deviations from the plan can also incur additional costs.

Although these problems are important, the other side of the problem is equally important. An unduly short program may result in an immature technology being deployed, with associated loss of capability relative to expectations and substantial modification and maintenance costs.

Despite the importance of the problem, there is little unambiguous evidence for resolving these issues. This analysis has attempted to contribute some useful information to the debate. In particular, we have tried to document trends in program duration over the last few decades and the factors that affect program length. Additionally, we have tried to identify possible policy options for shortening the acquisition cycle.

It is important to remember that this research is subject to two general constraints of schedule analysis. First, the lack of documentation on the rationale for the original plan limits insight into both the factors affecting that plan and why the actual program deviated from the plan. Second, since many factors can potentially affect program duration, and our database contains only a few programs, meaningful statistical analysis is infeasible. These inherent constraints suggest a need for a generally heuristic approach.

QUANTITATIVE RESULTS

A broad survey of aerospace weapon systems developed since the 1950s somewhat supports the assertion that program duration has increased. Programs begun in the 1970s and 1980s appear to take about one year longer in each of Phase I and Phase II than programs from the 1950s and 1960s. Although this difference is statistically significant, the data show very high program-to-program variation in any given time period, making prediction of schedule outcomes based on the year of program start infeasible. The small trend documented in this analysis provides some support for the claims of increasing program length, but that by itself does not provide any insight into the factors that drive program duration, and hence the trend, or how important the trend actually is in terms of its effect on acquisition cost or system performance, the two other common output measures.

The large variation in program duration and the large list of independent parameters that could possibly affect program duration suggest that multiple initiatives in policy and procedures will probably be necessary to achieve large changes in program durations. Acquisition policymakers should be inherently suspicious of simple, narrowly focused policy changes. For instance, Phase I (pre-FSD start) accounted for slightly over three years on average, or about one-third of the total program duration. Thus, even if Phase I times were cut in half (for example), that would yield only about a 15 percent reduction in overall program duration. Although our data do not unambiguously support it, reducing the time spent in Phase I this dramatically could result in high schedule slip in later program phases, and possibly poor initial performance as well. The LANTIRN and AMRAAM programs are partial examples of this.

The major factors that affect schedule slip are external guidance, technical difficulty, funding stability, and external events. All but technical difficulty can be classified as a factor external to the program and not attributable to the plan (but definitely affecting execution). Technical difficulty can be controlled only by seeking smaller advances in system capabilities, a somewhat controversial notion and certainly not reflective of past practice. DoD agencies and/or Congress can control external factors, however. In our sample of ten programs, removing the effect of external factors results in an average reduction of 11 percent in actual program length, or about one year, a substantial amount of time. It also corresponds with the average increase in program length between pre- and post-1970 programs. In practice, removing the effects of external factors means providing increased program stability in terms of funding, requirements, and guidance. This agrees with the results of previous studies.[1]

On average, the programs in our sample incurred a schedule slip that was one-third of the length of the original plans, and one-quarter of the length of the actual schedule outcome. About half of the slip was

[1]See, for example, Air Force System Command, *The Affordable Acquisition Approach Study*, February 1983.

due to external factors. Our analysis shows that if the effects of these factors are mitigated, most actual program schedule outcomes are fairly close to their plans. The remaining slip is dominated by technical difficulty, as shown by the AMRAAM, JTIDS, and LANTIRN programs. This suggests that the time required to develop technologically advanced or complex systems is often underestimated. The policy implication is that more time should be allowed for design and development when the program is characterized by a high degree of technical uncertainty. The problem is identifying this uncertainty and structuring a policy environment and decision process that can cope with it. This research did not address these two important issues.

SOME UNPROVED HYPOTHESES

As part of the analysis, we were interested in identifying relationships between some of the variables examined here, which might help to formulate policy and better understand the tradeoffs implicit in any given decision. Specifically, we looked for relationships between

- The plan and subsequent deviation.
- Cost growth and schedule slip.
- Time spent in Phase I and program slip.

The results of the analysis were mixed with respect to the relationship of the plan and deviation from it. One plausible hypothesis is that the length of the plan is closely associated with schedule slip. This relationship is through the mechanism of program execution: Short programs are hypothesized to be inherently more difficult to execute and therefore subject to potentially more schedule deviation than longer planned programs. Although this premise seems likely, we were unable to validate it. Some programs with short plans achieved those objectives, but others did not. The difference seems to lie in the way technical advance was incorporated into the plan. Additionally, some programs with long plans were poorly executed for one reason or another, resulting in substantial slip.

Similarly, we could find no relationship between cost growth and schedule slip. Both of these variables are measures of program success, and two hypotheses about their relationship are commonly asserted: (1) that there are tradeoffs between cost and schedule growth such that a program can incur one and not the other, and (2) that they in fact occur together in problematic programs. Even though these two hypotheses are opposed to each other, we can find no support for either in our data.

A hypothesis generated from research at RAND was that time spent in Phase I, often building and testing one or more prototypes, is time well spent. We would expect programs that spent proportionally more time and effort in Phase I to have a smoother Phase II and hence a better program outcome as measured by schedule slip. We found no such correlation.

GLOBAL OBSERVATIONS

During the course of this study and in other related research, we made several general observations concerning the length of the acquisition cycle and the factors affecting this length. We present them here more in terms of topics for future research than as results.

Schedule realism is apparently not examined as carefully at milestone decision points as are cost and performance estimates. In the case of cost, many well developed methods exist for testing cost realism; and at least one agency, the Cost Analysis Improvement Group, is entirely devoted to evaluating cost estimates at important decision points during program development. An institutional advocate for schedule realism and a mechanism for increasing the visibility of schedule estimates do not exist. Similarly, there are no formal schedule estimating relationship models and historical data to help in this task. The value of both increased schedule visibility and modeling should be explored as a future research task.

A related hypothesis is that programs appear to be getting longer because the regulations resulting from the implementation of OMB Circular A-109 have inserted more visibility and structure into some aspects of the planning process.[2] In fact, A-109 mandated this visibility by formalizing a program start milestone. We do not have any information that would show whether A-109 introduced more planning or just made the same amount of planning more visible and more easily linked to a specific project.

We suspect that technical and/or program complexity concerns are the major factors in actual schedule outcomes, after external factors have been removed. Our analysis lends some support to this notion. A common assertion is that the trend toward increasing program duration is at least in part due to increased technical and program complexity. If true, we believe that the problem lies in how these factors are handled in the planning process. However, we were unable to adequately explore this issue because of a lack of visibility into the planning

[2]OMB Circular A-109, published in April 1976, forms the basis for much of past and current acquisition policy as reflected in DoD Directive 5000-1 "Major and Non-Major Acquisition Programs."

process. Two future research topics arise out of this observation. First, a mechanism allowing greater visibility into schedule planning at program conception might be a valuable policy tool, provided that it does not cause an increase in burden on direct program management. Second, a method for assessing technical and program complexity, within a framework similar to that used here, may provide substantial additional insight into program schedule outcomes.

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Appendix A

SUPPORTING DATA

The tables in this appendix provide supporting data for the analysis in Sec. IV.

Table A.1 provides the raw data associated with Table 2. This includes the planned and actual intervals between milestones as well as the calculation of slip in both absolute and percentage terms. Additionally, Table A.1 provides data supporting Figs. 11 and 12: the ratio of time spent in Phase I relative to Phase II, and cost growth factors for each program.

Table A.2 describes the events associated with each factor affecting the original plan and provides the rationale for the probable direction of effect on the plan. These data support Table 3.

Table A.3 supports the data in Table 4. For each program, the event associated with each factor is provided, along with the number of months of slip in the first delivery milestone and the change in first delivery dates associated with the revised plan that resulted from the slip.

Table A.1

ADDITIONAL PROGRAM DATA

Program	Phase I (months) Plan (1)	Phase I (months) Actual (1)	Phase II (months) Plan (2)	Phase II (months) Actual (2)	Total Length (mo.) Plan (3)	Total Length (mo.) Actual (3)	Phase I Slip (months) (4)	Phase II Slip (months) (5)	Total Slip (months) (6)
MLRS	40	39	21	28	61	67	−1	7	6
A-10	33	33	34	34	67	67	0	0	0
DIVAD	9	11	55	74	64	85	2	19	21
M-1	43	48	40	39	83	87	5	−1	4
AH-64	44	51	47	85	91	136	7	38	45
F/A-18	16	20	57	53	73	73	4	−4	0
LANTIRN	3	9	53	94	56	103	6	41	47
AMRAAM	37	37	44	81	81	118	0	37	37
GPS	51	66	85	95	136	161	15	10	25
JTIDS	59	76	55	128	114	204	17	73	90
Average	33.5	39	49.1	71.1	82.6	110.1	5.5	22	27.5

Col. (1) Months from Milestone I to FSD start.
Col. (2) Months from FSD start to first operational delivery.
Col. (3) Months from Milestone I to first operational delivery.
Col. (4) Phase I (actual) – Phase I (plan). Slip in time from program start to FSD start.
Col. (5) Phase II (actual) – Phase II (plan). Slip in time from FSD start to 1st delivery.
Col. (6) Total program (actual) – Total program (plan). Slip from program start to first delivery.

Table A.1—continued

Program	% Slip Phase I (plan) (7)	% Slip Phase II (plan) (8)	% Slip Total (plan) (9)	Ratio Phase I to Phase II (plan) (10)	Ratio Phase I to Phase II (actual) (11)	Ratio Phase I to Total Program (plan) (12)	Ratio Phase I to Total Program (actual) (13)	Cost Growth (14)
MLRS	−2.5	33.0	9.8	1.90	1.40	.65	.58	.92
A-10	0	0	0	.97	.97	.49	.49	1.29
DIVAD	22.2	34.5	32.8	.16	.15	.14	.13	1.05
M-1	11.6	−2.5	4.8	1.07	1.20	.52	.55	1.54
AH-64	15.9	80.8	49.4	.93	.60	.48	.37	1.58
F/A-18	25.0	−7.0	0	.28	.38	.21	.27	1.31
LANTIRN	200	77.3	83.9	.06	.09	.05	.09	1.15
AMRAAM	0	84.1	45.7	.84	.46	.46	.31	1.18
GPS	29.4	11.7	18.4	.60	.69	.37	.41	1.05
JTIDS	28.8	132.7	78.9	1.07	.59	.51	.37	1.28
Average	33	44	32	.79	.66	.39	.36	1.24

Col. (7) Phase I slip/Phase I plan × 100.
Col. (8) Phase II slip/Phase II plan × 100.
Col. (9) Total slip/Total planned length × 100.
Col. (10) Phase I/Phase II in mo. (plan).
Col. (11) Phase I/Phase II in mo. (actual).
Col. (12) Phase I/Total planned length in mo.
Col. (13) Phase I/Total actual length in mo.
Col (14) December 88 current estimate/development estimate, normalized for inflation and quantity.

NOTES:

MLRS: Program start: DSARC I
FSD start: maturity contract award
1st delivery: delivery of SPLL (1st available complete system)

A-10: Program start: SPO established
FSD start: DSARC II

DIVAD: Program start: DSARC I
FSD start: DSARC II and FSD contract award

M-1: Program start: DSARC I
FSD start: DSARC II and FSD contract award
1st delivery: planned date assumed - to DT/OT III start

AH-64: Program start: DSARC I
FSD start: DSARC II and FSD contract award

F/A-18: Program start: VFAX approval (dual role fighter)
FSD start: DSARC II (plan from AW&ST May 75)
1st delivery: plan is assumed, but makes sense relative to test program (from N-2599)

Table A.1—continued

LANTIRN:	**Program start:** AF HQ direction to solicit bids (PMD)
	FSD start: contract award for FCS
	1st delivery: target pod data
AMRAAM:	**Program start:** DSARC I
	FSD start: contract award
	1st delivery: quarterly mid-points used for plan and December 87 SAR estimate
GPS:	**Program start:** DSARC I
	FSD start: DSARC II
	1st delivery: planned date assumed
JTIDS: (TDMA)	**Program start:** OSD direction to combine AF SEEK BUS and Navy ITACS & ITNS into JTIDS
	FSD start: Milestone II & FSD C/A (January 79 PMD and June 82 SAR DE)
	1st delivery: AF TDMA Class 2 (January 79 PMD and December 87 SAR): assumed = DT/OT III start (plan)

Table A.2

FACTORS AFFECTING THE ORIGINAL PLAN

	MLRS	A-10
Competition	Competitive demonstration/validation phase tends to lengthen planned programs.	A competitive prototype phase was planned from the outset and may have increased plan length.
Concurrency	High degree of concurrency, including combined testing and replacement of FSD phase with a maturity phase, tended to shorten the plan.	The program was concurrent in FSD/production; tests were not completed before production release.
Prototype Phase	*Fabrication of competitive prototypes tends to lengthen a* plan: more time needed for "shoot-off" and evaluation than a paper competition.	*The competitive prototype phase* planned from the outset may have increased plan length.
Separate Contracting	Maturity and production contracts were planned to be awarded concurrently if the prototypes were mature.	
External Guidance	Both Congress and the Army wanted to field the system as soon as possible. An accelerated strategy was approved.	Guidance to prototype came from OSD: Deputy Secretary of Defense Packard's "fly-before-buy" strategy. The Air Force offered the A-10 as their candidate.
	F/A-18	**LANTIRN**
Concurrency	Program was highly concurrent. DSARC II approved FY79 release of the first nine low rate production aircraft, as well as the 11 FSD articles.	Highly concurrent in FSD/production, planned from the outset. Initial contract included production options.
Funding Adequacy	Program was adequately funded.	
Separate Contracting		Contracting strategy resembled a total package procurement. No separate contracts between FSD and production phases.

Table A.2—continued

	F/A-18	LANTIRN
Service Priority		High service priority to improve night attack and low level navigation capabilities. Also was seen as a "force multiplier" through the automatic target recognition component.
External Guidance	Congressional direction to choose one of the Air Force's Light Weight Fighter prototypes probably reduced the amount of development effort necessary before entering FSD. The front end of the program was shortened.	The original Program Management Directive was the basis for the original plan. The schedule in the PMD was based on an earlier plan that included a very short, highly ambitious schedule.
	DIVAD	**M-1**
Competition	Competitive prototype phase during the first part of FSD may have added time. This seems to have been planned from the outset.	Inclusion of a competitive demonstration/validation phase tends to lengthen plan. This was directed by Congress at XM-803 termination.
Concurrency	Program was concurrent in FSD/production and testing program. Production options were contained in the maturity contract before Milestone III.	Direction to shorten acquisition cycle led to inclusion of concurrency.
Prototype Phase	Competitive prototype phase during the first part of FSD may have added time. This seems to have been planned from the outset.	Added shoot-off and evaluation time makes competitive prototype development plans longer than paper competition.
Service Priority	High priority to fill a perceived gap in air defense.	High service priority to field a new tank led to shorter program plan.
External Guidance	Army guidance, with Congressional approval, to use accelerated acquisition approach.	Army Chief of Staff directed that new tank be fielded in six years.

Table A.2—continued

	GPS	JTIDS
Separate Contracting		There were separate contracts for Phase I, Phase II, and production.
Service Priority	Joint management meant that GPS was a low priority program relative to the services mission specific programs. There is an implied issue of funding adequacy here.	Each service claimed that JTIDS was high priority, as it provided an urgently needed capability (secure, jam-resistant communications) not currently fulfilled by any other deployed or planned system.
External Guidance		OSD direction to combine Air Force SEEK BUS and Navy ITACS and ITNS programs.
Joint Management	No service considered GPS as important as their mission specific specialty programs. This may have encouraged the lack of concurrency and the use of separate contracting.	Interservice coordination complicates program planning and budgeting, especially given the different operational concepts of the services.
Program Complexity	Interactions with at least 73 other programs in all 3 services for integration of GPS user equipment on the various platforms must be allowed for.	JTIDS was to be integrated into many different platforms, including Navy ships, antisubmarine warfare platforms, Navy and Air Force airborne early warning systems (E-2C, E-3A), tactical fighter and attack aircraft, and the Army's air defense systems. NATO interoperability was also a concern.
	AMRAAM	**AH-64**
Competition	Competitive demonstration/validation phase tends to lengthen the plan.	Included a competitive prototype phase, planned from the outset.
Concurrency	External direction to shorten plan by increasing concurrency.	No concurrency at all, reflecting Army Aviation Systems Command style of sequential development.

Table A.2—continued

	AMRAAM	AH-64
Funding Adequacy		Program was adequately funded, reflecting high service priority.
Prototype Phase	Added shoot-off and evaluation time makes competitive prototype development plans longer than paper competition.	
Separate Contracting	Production options were in FSD contract. No separate contracting tends to shorten plan.	There were distinct phases with separate contracts for each.
Service Priority	High priority led to inclusion of concurrency.	
External Guidance	Direction to shorten plan by adding concurrency.	
Joint Management	Joint programs require interservice coordination and cooperation, resulting in somewhat longer plans.	

Table A.3

FACTORS AFFECTING PROGRAM SLIP

	MLRS	A-10
Contractor Performance	One month slip (July '82 to August '82) due to production start-up problems.	
External Event	Five month slip (February '82 to August '82) due to worker strike at FMC plant producing SPLLS.	
Funding Stability		Four month slip due to Congressional deletion of FY74 procurement funds. Because four RDT&E aircraft were reprogrammed to procurement account, 1st RDT&E aircraft is the first production delivery and original milestone was met.

	DIVAD	M-1
Contractor Performance	Five month slip (September '83 to February '84) due to inadequate deliveries of FACCs, in house electronics and mechanical assemblies. One month slip (to March '84: actual date) due to start-up problems.	
Funding Stability	Six month slip (June '82 to December '82) to allow for additional lead time (FY81 funding reduction). Four month slip (December '82 to April '83) due to cancellation of FY81 procurement funds. Four month slip (April '83 to August '83) due to FY82 amended budget.	

Table A.3—continued

	DIVAD	M-1
	One month slip (August '83 to September '83) due to delay in source selection as a result of change in administrations and new budget.	
External Guidance		Four month slip (October '79 to February '80) due to Secretary of Defense's decision to delay FSD contract award.
	LANTIRN	**F/A-18**
Technical Difficulty	20 months slip as part of the September '81 32 months restructure (December '84 to August '87). Dropped ATR and had integration and software problems. 11 months slip (August '87 to July '88) in target pod problems. Again software and integration problems.	No known delays in first production delivery date. However, this was never a SAR milestone, and first delivery appears to have occurred before the Milestone III production decision.
Concept Stability	Four months (August '84 to December '84) because of internal AF debate over system concept, complicated by funding constraints. This is the time between the March '80 and September '80 acquisition plans, less two months.	
Funding Stability	12 months slip as part of September '81 restructure. Adequacy and uncertainty regarding funding profile in out-years.	
	AMRAAM	**AH-64**
External Guidance	Three month slip (June '88 to September '89) because of delay in release of manpower package to Congress, which resulted in delay of Lot 1 contract award.	11 month slip because of long lead time approval (July '79). Two month slip because of delay in DSARC III causing delay in production contract award (December '81).

Table A.3—continued

	AMRAAM	AH-64
Technical Difficulty	24 month slip (June '86 to June '88) because of hardware/software integration problems. Change in requirements (solid state transmitter to traveling wave tube) causing redesign; slow contractor reaction to technical problems also played a role. Five month slip (portion of 10 month slip from August '85 to June '86) because of contractor technical problems.	Five month extension (October '76) to prototype phase to permit correction of several technical problems.
External Event		Six month (March '75) slip because of cost growth from unexpected inflation. Army waited till following year to absorb costs. One month slip because of crash (November '80) not system related.
Funding Stability	Five month slip (portion of 10 month slip from August '85 to June '86) because of funding availability.	Five month slip (July '75) because of Congressional delay in releasing long lead funds. Ten month (January '77) slip because of budget cut. Regained four months of the ten month delay by partial restoration of budget (July '77).
Requirements Stability		Five month (February '76) slip for change to Hellfire. Four month (March '76) slip for change to TADS/PNVS.

	GPS	JTIDS
External Guidance	Eight month delay (April '85 to December '85) because contract award slipped (Congressional reprogramming action). Five month additional delay (December '85 to May	Two month slip (portion of May '88 to March '89 slip) for revised DT&E review cycle and 27 month slip for Congressional direction to demonstrate 400 hour mean time between failure reliability (June '89 to September '91).

Table A.3—continued

	GPS	JTIDS
Program Complexity		Incorporation of TADIL J message standard written by JCS office caused redesign and appears to have accounted for about five months of the 11 month slip from June '87 to May '88.
Technical Difficulty	Five month delay (August '86 to January '87) because of technical problems associated with moving the first satellite through the production line.	Hardware/software integration problems led to two different six month delays: a portion of the 11 month slip from June '87 to May '88 and a portion of the 10 month slip from May '88 to March '89.
External Event	Four month delay (January '87 to May '87) for launch restructure.	Two month slip to test asset availability (portion of the May '88 to March '89 slip), and three month slip for delay in F-15 test aircraft arrival at Eglin AFB (March '89 to June '89).
Funding Stability	Three month delay (May '86 to August '86) for negotiations that established August '86 as earliest date for launch-ready satellite given approved funding levels of FY85 budget.	
Requirements Stability		12 month acceleration (June '88 to June '87) for a reduction in testing program requirements. The level of performance demonstrated before production decision was apparently reduced. There is an implied funding constraint as well.
Unknown		51 months slip (March '84 to June '88) incurred during Phase I.

Appendix B

A-10 PROGRAM

This appendix briefly describes the factors affecting the pace of the A-10 program. The A-10 is a single seat, twin engine aircraft specifically designed for the close air support (CAS) mission. It is armed with a high velocity, rapid fire 30mm gun and can carry 16,000 lb of external ordnance. The information presented here comes from various sources, including public literature and official program documentation.

BACKGROUND

The Air Force began studying the CAS concept in 1966 in part as a response to the Army's Cheyenne (AH-56) attack helicopter program. In May 1967, contracts were awarded to General Dynamics/Convair Division, Grumman, McDonnell Douglas, and Northrop to study CAS design concepts. The CAS aircraft was perceived as a simple aircraft with limited avionics and low operation and maintenance costs. In May 1968, the Air Force published the A-X Concept Formulation Package to justify conditional approval of concept and engineering development phases. However, OSD approval was not forthcoming at that time. An A-X decision coordinating paper (DCP) was signed in December 1968, but implementation of the concept phase (contract definition) was delayed by the Director, Defense Research and Engineering (DDR&E) to reexamine some of the CAS issues.

In June 1969, the Air Force published an A-X Technical Development Plan which conceived of a CAS aircraft as a highly survivable, short takeoff and landing (STOL) capable, maneuverable aircraft using existing technology. The technical development paper (TDP) proposed an acquisition plan that included FSD start in FY70, source selection after an unfunded design competition, a single FSD/production contract, and a single contract for the engine. In particular, RFPs were to be released to industry in September 1969 with FSD contracts awarded in January 1970. First flight was planned for December 1971 and first production delivery was planned for April 1972, 27 months after contract award. IOC was planned for February 1973. This was a very short schedule, with IOC occurring 37 months after contract award. However, this plan was not approved.

In September 1969, a supplement to the Concept Formulation Package was sent to the Secretary of Defense. In October, the Secretary of the Air Force approved a competitive prototyping approach for the A-X. A DSARC review occurred in December 1969 granting approval to proceed through the validation phase. The Deputy Secretary of Defense approved the A-X competitive prototyping approach in April 1970 and directed the establishment of an A-X system program office (SPO) at aeronautical systems division (ASD). This marks formal program initiation for the A-10 program.

The A-10 was managed in a system program office in the Aeronautical Systems Division of the Air Force Systems Command. The primary user is the Air Force Tactical Air Command.

The A-10 was the first Air Force aircraft designed specifically for the CAS mission. This included antiarmor roles in an intense antiaircraft environment. It was conceived as a conventional aircraft using existing technology with the minimum of avionics for the CAS mission. It is well armored, particularly around the cockpit, and has self-sealing fuel tanks. Design criteria included survivability, STOL capability to operate from forward airfields, and maneuverability at slow speeds. The four basic requirements for the A-10 included survivability, combat effectiveness, simplicity, and responsiveness. The A-10 is a single seat, twin turbofan (TF-34) aircraft with a high velocity rapid fire 30mm gatling gun (GAU-8). It can carry 16,000 lb of external ordnance at speeds from 150 to 450 knots. Its primary antiarmor missile is the Maverick. The aircraft is essentially state of the art with few technical risks.

ORIGINAL PLAN

The original plan at the time of program initiation (April 1970) included a competitive prototype phase followed by an FSD phase and initial production. The prototyping phase was in response to then Deputy Secretary of Defense Packard's prototyping initiative. During Phase I, two contractors would design and fabricate two prototypes each for competitive test and evaluation. First flights of the prototypes were to occur in June 1972 followed by five months of contractor testing and a two month government competitive evaluation. DSARC II was planned for January 1973 with an FSD contract award to the winning contractor the following month. Ten DT&E aircraft were to be fabricated during FSD. DSARC IIIa for initial production approval was planned for May 1974 with first delivery scheduled for November 1975. IOC was planned for June 1977.

The original plan was 67 months in length from program initiation to first production delivery. While no concurrency was planned during Phase I (validation phase with prototypes), Phase II (FSD) did include some degree of concurrency. This is shown by the planned DSARC IIIa initial production approval in May 1974 before the first flight of the first development test and evaluation (DT&E) aircraft. This concurrency was acceptable probably because of the experience expected to be gained during prototyping, the availability of prototype aircraft for testing during FSD, and the low technical risk associated with development of an essentially conventional subsonic aircraft. Other characteristics of the acquisition plan included a high degree of SPO autonomy and management and tradeoff decision flexibility allowed the contractor. A design to cost goal was established at approximately $1.4 million (FY70$) per aircraft at a 20 aircraft per month production rate for 600 aircraft.

Several factors appear to have influenced the length of the original plan. External guidance to include a prototyping phase and making this phase competitive may have lengthened the plan. In fact, including these acquisition strategy elements seems to have lengthened the original plan by about 30 months over the earlier proposed plan in the June 1969 TDP, which did not include a competitive prototyping phase. Additionally, the inclusion of development-production concurrency may have shortened the FSD phase of the program.

EVENTS AND DEVIATIONS

Table B.1 shows selected schedule milestones for the A-10 program. The dates under the revised plan columns indicate when schedule changes were documented. There were several changes to the original plan, including first production delivery. However, measured from the establishment of the A-X SPO to first production delivery, the total program length was 67 months with no slip in first delivery. Although many of the program milestones did slip, including first delivery, the program later recovered much of this slip.

Phase I

In May 1970, RFPs were released to 12 firms for the A-X competitive prototype phase. Six firms responded in August. DSARC I, which formally approved entry into the prototyping phase, occurred in December 1970. The same month, contracts were awarded to Northrop and Fairchild Republic ($28.8 million and $41.2 million respectively)

Table B.1

A-10 MILESTONE TABLE

Milestone	Original Plan[a] (Jun 71)	Revised Plan[b] (Mar 73)	Revised Plan[c] (Dec 73)	Revised Plan[d] (Sep 74)	Revised Plan[e] (Dec 74)	Revised Plan[f] (Dec 75)	Revised Plan[g] (Dec 76)	Revised Plan[h] (Mar 78)	Actual Date[j] (Mar 78)
A-X SPO established	Apr 70								Apr 70
DSARC I	Dec 70								Dec 70
Prototype 1st flight	Jun 72	May 72							May 72
DSARC II	Jan 73								Jan 73
FSD contract award	Feb 73	Mar 73							Mar 73
Complete 30mm gun/									
A-10 proto demo	Apr 74			May 74					May 74
DSARC IIIa (IP)	May 74		Jun 74	Jul 74					Jul 74
Release FY74 adv. buy									
production funds	May 74		Jul 74	N/A					
Release FY75 long lead									
production funds	N/A			Jul 74					Jul 74
Engine qualification test									Oct 74
complete	Oct 74								Dec 74
Release FY75 production	Sep 74	Nov 74			Dec 74				Feb 75
1st flight DT&E aircraft	Dec 74			Feb 75					
Deliver 1st IOT&E aircraft	Jun 75		Sep 75	Nov 75	N/A				
Release FY76 production									
(run A)	Jul 75								Jul 75
DSARC IIIb (FP)	Oct 75					Jan 76	Feb 76		Feb 76
Release FY76 production									
(run B)	Nov 75					Jan 76	Feb 76		Feb 76
Deliver 1st production aircraft	Nov 75		Mar 76	Nov 75					Nov 75
IOC	Jun 77		Dec 77		Jan 78			Oct 77	Oct 77

Table B.1—continued

NOTES:

[a]30 Jun 71 SAR development estimate (DE), 31 Dec 72 SAR planning estimate (PE), and 31 Mar 73 SAR (PE): This was the original plan at DSARC I. There was a very different earlier plan proposed in a June 1969 Technical Development Plan for the A-X, but program initiation is here designated as DSARC I.

[b]31 Mar 73 SAR current estimate (CE): FSD contracts were delayed because of Congressional interest in source selection and OSD direction that contracts not be let until completion of CAIG review. Release of FY75 production funds delayed to allow completion of engine qualification test at OSD direction.

[c]31 Dec 73 SAR (CE): Congressional deletion of FY74 long lead production funds caused schedule slippage as shown. DT&E preproduction aircraft reduced from ten to six, delaying IOT&E aircraft delivery.

[d]30 Sep 74 SAR (CE): Delay in 30mm gun/A-10 prototype demonstration because of secondary gun gas ingestion problems. DSARC IIIa delayed because of Congressional deletion of FY74 procurement funds. DT&E aircraft first flight delayed because of late receipt of vendor items, tooling, and critical materials. (IOT&E aircraft delivery also.) Transfer of four RDT&E aircraft to procurement account allowed acceleration of production schedule. IOT&E aircraft is the first production unit.

[e]31 Dec 74 SAR (CE): Funding for FY75 buy was released in Dec 74 subsequent to DSARC briefing. Congressional action to procure fewer aircraft in FY75 resulted in slower equippage of operational units, thus delaying IOC.

[f]31 Dec 75 SAR (CE): DSARC IIIb slipped three months before this SAR to provide time for required testing. This had slipped FY76 production release by two months. Additional slips because of one month additional delay in DSARC IIIb to provide more time for testing.

[g]31 Dec 76 SAR (CE): Additional slip in DSARC IIIb and FY76 production release because of testing requirements. DCP 23B signed and funds released in Feb 76.

[h]31 Mar 78 SAR (CE): IOC was apparently met in Oct 77.

[i]31 Mar 78 SAR (CE).

for two flying prototypes each, to be delivered for testing in June 1972. These prototypes were austere, with minimum avionics and armed with a 20mm gun rather than the planned 30mm gun (GAU-8). Integration of the GAU-8 was planned for FSD. The total planned length of Phase I was 26 months, from the December 1970 contract award to the planned FSD contract award in February 1973.

The prototypes were actually delivered one month early in May 1972. The Fairchild YA-10 first flew on May 10 and the Northrop YA-9 flew on May 30. The A-X RFP had called for a five month contractor flight test followed by a two month Air Force competitive flyoff, which started on schedule in October; by December 1972 the flyoff was complete. The Fairchild YA-10 was announced the winner of the competition in January 1973, and a DSARC II meeting approved entry into FSD.

During the prototype phase, the development of the 30mm gatling gun began. In June 1971, competitive prototype development contracts were awarded for the GAU-8. In September of that year, the gun program became a subprogram in the A-X SPO.

Phase II

Figure B.1 graphically illustrates the evolution of the A-10 program schedule. The original plan can be read off the horizontal axis, and each evolution of the plan is indicated by changes in the milestone lines. The vertical axis gives the date when schedule changes were reflected in program documentation. All milestone intervals are measured in months from program start (the establishment of the A-X SPO). The numbers show the months of slip (or recovery) associated with various events affecting the pace of the program.

Contract award for FSD, originally planned for February 1973, actually occurred one month late in March. This delay stems from Congressional interest in source selection and OSD direction not to award the FSD contract until after the CAIG review was complete. The cost plus incentive fee FSD contract, valued at $159 million, included fabrication of ten DT&E articles and the continuation of testing on the YA-10 prototypes. Also in March 1973, a contract was awarded to General Electric for the TF34-GE-100 turbofan engines. A minor restructuring of downstream milestones occurred with the delay of FY75 production fund release until after the engine qualification test was complete. This was a two month slip, from September to November 1974.

A more major restructure occurred in July 1973. Congress, at the initiative of the Senate Armed Services Committee, deleted the FY74

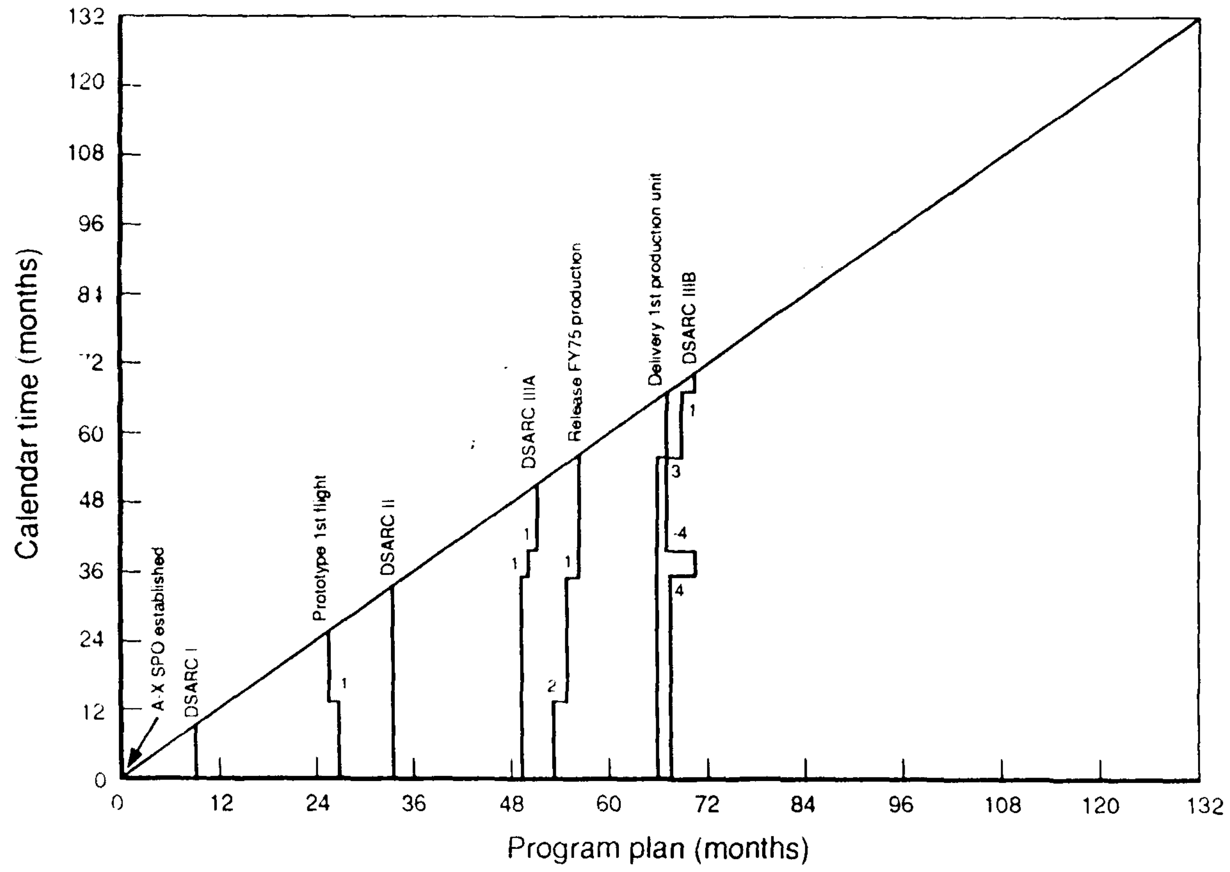

Fig. B.1—A-10 schedule evolution

long lead production funds (planned for May 74). This caused a one month slip in DSARC IIIa (from May to June 74), a three month slip in delivery of the first IOT&E aircraft (from June to September 75), a four month slip in first production unit delivery (from November 75 to March 76), and a six month slip in IOC (from June 77 to December 77). This funding cut also reduced the number of DT&E articles from ten to six. At the same time, Congress directed a flyoff between the A-7D and YA-10 for fulfillment of the CAS mission. This flyoff was completed in May 1974 and results supported the continued development of the A-10.

Technical problems with the GAU-8 30mm gun delayed the completion of the gun/prototype demonstration by one month (from April to May 74). These problems concerned gun gas ingestion and residual powder ignition. GE had won the gun prototype competition over Hughes in August 1973, and integration of the gun into a YA-10 prototype began in February 1974. DSARC IIIa was delayed an additional month (to July 74) because of the earlier budget cut by Congress. The first flight of the first DT&E aircraft was delayed from the planned date of December 1974 by two months (to February 75) because of late receipt of vendor items, tooling problems, and critical materials. This also delayed delivery of the first IOT&E aircraft until November 1975 (a two month slip). However, reprogramming the four deleted DT&E aircraft to the procurement account allowed acceleration of the production schedule, and the delivery of the first IOT&E unit became the first production unit delivery (planned for November 75).

Release of FY74 production funds occurred in December 1974 subsequent to the July 1974 DSARC IIIa. The first DT&E aircraft flew in February 1975 and by September the last DT&E aircraft had been delivered. The two YA-10 prototypes had supported FSD testing until January 1975. Congressional action to procure fewer aircraft in FY75 resulted in a one month slip in IOC (from December 77 to January 78), but the first production delivery was made as planned in November 1975. DSARC IIIb (full production) had slipped three months (October 75 to January 76) to allow more time for testing, and it slipped an additional month for the same reason. This in turn delayed release of FY76 production funds. IOC occurred in October 1977.

SUMMARY

Table B.2 summarizes the factors affecting the pace of the A-10 program. The total planned program length was 67 months from program start (A-X SPO establishment) to first production delivery. Measured

Table B.2

FACTORS AFFECTING PACE—A-10

	Original Plan	Deviation from Plan
Competition	L	
Concurrency	S	
Funding adequacy		
Prototype phase	L	
Separate contracting		
Service priority		
External guidance	L	
Joint management		
Program complexity		
Technical difficulty		
Concept stability		
Contractor performance		
External event		
Funding stability		4 (FY74 deletion of procurement funds)
		−4 (Reprogramming 4 RDT&E aircraft to procurement)
Major requirements stability		
Program manager turnover		
Total accounted for		(0)
Unknown		
Total slip to first delivery		0

in this way, the program experienced no slip in first delivery, though several schedule milestones did in fact vary somewhat over the life of the program.

Four factors appear to have most strongly influenced the length of the original plan. The external guidance (from OSD) to add competition and prototyping seems to have lengthened the plan. In fact, the 30 month difference between the proposed plan of June 1969 (in the TDP) and the approved plan at program initiation may be attributable to adding the competitive prototype phase. Concurrency in development-production, indicated by the fact that DSARC IIIa decision was planned to occur seven months before the first flight of a DT&E aircraft, probably contributed to shortening the program. Overall the original plan appears to have been short.

Budget instability caused a four month delay in first production delivery. However, the program compensated for this by a reprogramming action. In the end, there was no slip in first production delivery.

However, several of the interim milestones related to testing did slip, mainly from technical problems and perhaps the lack of skilled production workers at the Fairchild plant. An interesting factor that perhaps had an effect different than we would have expected is service priority. Supporting Army ground troops (the CAS mission) had never been a high priority mission of the Air Force, and therefore the A-10 was a low priority program. Although we might have expected that this would make both the plan and the actual schedule longer, it seems to have acted as a disincentive to the Air Force hierarchy in changing the program. This may have allowed the program to run somewhat smoother.

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Appendix C

ADVANCED MEDIUM RANGE AIR-TO-AIR MISSILE (AMRAAM)

This appendix briefly summarizes the factors affecting the pace of the Advanced Medium Range Air-to-Air Missile (AMRAAM), a joint Air Force/Navy program to develop a follow-on to the Sparrow. AMRAAM is an all-weather, all-aspect air-to-air missile with an active seeker and launch and leave capability. The information contained here comes from public literature, program documentation, and interviews with program office personnel.

BACKGROUND

In July 1975, a proposed prototyping program for an advanced tactical air-to-air missile was presented to the Air Council and approved for a FY77 start. This was to be a follow-on program to the existing Sparrow missile. A 13 month study was directed by DoD in September 1975 with Air Force, Navy, and Marine Corp participation. A July 1976 memorandum from the DDR&E to the Assistant Secretaries for R&D of the Air Force and Navy directed initiation of a joint program for an advanced beyond visual range air-to-air missile (Sparrow follow-on) with the Air Force as the lead agency. The program was to use a prototyping approach. The concept exploration effort actually began in June 1976 and involved five contractors.[1] Tasks Tasks for this effort included design and analysis of missile guidance systems, preliminary design of missile concepts, cost and logistics studies, and fabrication and testing critical subsystem components. This phase was completed in May 1978. In parallel with the concept exploration phase, a Joint System Operational Requirements (JSORs) document was developed and a draft was released in September 1976. As a result of the concept studies, the JSOR was revised in April 1978 and formally validated in September 1978.

AMRAAM is an advanced medium range all-weather, all-aspect missile effective both within and beyond visual range. A March 1978

[1]Ford Aerospace, Hughes, General Dynamics, Raytheon, and Northrop.

PMD, based on the JSOR, set the baseline design characteristics of AMRAAM. These included

- A launch and leave capability.
- Increased velocity over the Sparrow.
- Reduced miss, improved fuzing, and increased warhead lethality.
- Electronic counter-countermeasures capability.
- Ability to attack multiple targets.
- Compatibility with the F-14, F-15, F-16, F-18, and several NATO aircraft.

These characteristics imply a large advance over the Sparrow. Missions include air defense, fighter escort, and fighter sweep for the Air Force, and fleet air defense, beachhead defense, and strike escort for the Navy.

AMRAAM is managed by a joint system program office (JSPO) with the Air Force as the lead agency. Participating commands include the Air Force Systems Command (AFSC) and the Naval Air Systems Command. The JSPO is located at Eglin AFB in Florida, which previously had been a testing rather than a development AFB. Tactical Air Command (TAC) is the major Air Force user.

ORIGINAL PLAN

In early 1978, Commander, AFSC wanted AMRAAM development time accelerated from approximately 90 months (as planned in an October 1976 PMD governing concept exploration) to about 70 months to meet the desired TAC IOC and Congressional concerns about the length of the acquisition process. TAC operational urgency appears to have been the overriding concern here. A March 1978 AFSC study compared the 90 month proposed schedule with alternatives of 70, 54, and 42 months. The study concluded that concurrency and increased risks would be associated with any of these alternatives. The March 1978 PMD appears to be based on the approximately 70 month schedule. In August 1978, the AFSC Commander approved the plan and RFPs were released that included a 33 month validation phase and a 40 month FSD phase, with production beginning in 1985 and a late 1985 IOC. The accelerated schedule was developed by eliminating sequential pilot production, reducing IOT&E, and combining IOT&E with DT&E during FSD.

The validation phase was to begin in January 1979 with contract awards to two contractors for a competitive prototype phase. Each contractor was to build 16 prototypes for testing. The FSD phase was to begin the first quarter of FY82 with the award of a single contract to the winner of the competitive evaluation. This contract was to include approximately 90 test articles and three production options (two prepriced, one unpriced) for 164, 656, and 1524 missiles respectively. The validation phase contracts were to be firm fixed price, and the FSD contract was to be a fixed price incentive contract. Production planning was already envisioned to include NATO coproduction and leader/follower production in the United States.

DSARC I occurred in November 1978 and approved the baseline plan as described in the March 1978 PMD. To be consistent with the other programs examined in this study, DSARC I constitutes formal program initiation. Key program risks identified at the time of DSARC I included multi-aircraft compatibility (avionics integration and data links), the solid-state transmitter (power, cooling, reliability), software development, the new fuze, and the missile environment.

Many factors appear to influence the length of the original plan. There was a great deal of competition in the program beginning in the concept exploration phase with five contractors and continuing into the validation phase with two contractors. The design, fabrication, and testing of prototypes from the two validation phase contractors were also planned from the outset. Additionally, the program was originally conceived as a joint Air Force/Navy effort. These three factors appear to have made the program somewhat longer than it otherwise might have been.

Four factors influenced the plan to be shorter than implied by the competitive prototype and joint management factors. External guidance to accelerate the schedule, which reflects the high service priority for the program; the inclusion of a high degree of concurrency between development and production as reflected in the testing program (combined DT&E/IOT&E); the lack of separate contracts for FSD; and initial production all appear to have influenced the plan to be shorter. Though the evidence is ambiguous, these factors may account for the approximately 20 month difference between the proposed 90 month plan and the 70 month plan approved at DSARC I.

EVENTS AND DEVIATIONS

Table C.1 shows selected schedule milestones for the AMRAAM program. The dates under the revised plan columns indicate when a program change was documented. Measured from DSARC I until first production delivery, the original plan was 81 months in length. Using

Table C.1

AMRAAM MILESTONE TABLE

Milestone	Original Plan[a] (Mar 78)	Revised Plan[b] (Aug 78)	Revised Plan[c] (Nov 78)	Revised Plan[d] (Aug 81)	Revised Plan[e] (Dec 81)	Revised Plan[f] (Jul 82)	Revised Plan[g] (Dec 82)	Revised Plan[h] (Apr 84)	Revised Plan[j] (Sep 85)	Revised Plan[k] (Dec 86)	Actual Date[m] (Dec 87)
DSARC I	1QFY79										Nov 78
Validation contract	Jan 79	Feb 79									Feb 79
Preliminary design review							Aug 82				Aug 82
FSD contract	1QFY82	Nov 81			Dec 81						Dec 81
DSARC II	1QFY82			Nov 82		Aug 82	Sep 82				Sep 82
SDDM							Nov 82				Nov 82
AFSARC III (long lead Lot I)				Oct 83		Jun 84	2QFY84		3QFY86	Dec 86	Dec 86
Exercise production option (long lead Lot I)				3QFY84			Feb 84		N/A		
Production long lead Lot I									Jul 86		
Production contract full go-ahead Lot I										Jul 87	Oct 87
AFSARC III (Lot II production)						Oct 84	1QFY85		2QFY87		
DSARC III	2QFY85							Nov 85	Apr 87	Jun 87	Jun 87
1st production option							Nov 84		N/A		
1st production delivery	4QFY85		Sep 85	Jun 85		Aug 85		Jun 86	Jun 88		4QFY88 est
JRMB IIIb Lot III full rate production										Mar 89	Mar 89 est
IOC		Sep 85			Aug 86		4QFY86	Nov 87	3QFY89	Oct 89	Oct 89 est

NOTES:

[a] 7 November 78 DSARC I Briefing: Estimates from schedule chart (briefing chart #31) and reflects baseline as established in March 78 PMD.

Table C.1—continued

[b]GAO/NSIAD-87-78, March 87, p. 13-14 (extrapolation): A 33 month validation phase was to start in February 79, followed by a 40 month FSD phase. FSD was reduced from previous plan through use of concurrency. This plan was approved by the Commander AFSC in August 78.

[c]November 78 DSARC I Briefing: Firm date for IOC given (September 85). Otherwise, schedule is based on March 78 PMD.

[d]5 August 81 Acquisition Plan: Original baseline schedule of 7½ years (90 months) reduced to 6 years, 1 month (73 months) by eliminating sequential pilot production and reducing IOT&E. Operational urgency was cited as the need for concurrent schedule.

[e]Planned at FSD contract award (December 81). Unable to obtain reasonable bids for a 40 month FSD phase with IOC in September 85 as planned in August 78. Contractor signed up to a 50 month FSD phase with an August 86 IOC. Contract negotiations caused the 1 month slip in award.

[f]22 July 82 briefing: AF reviews indicated on schedule chart is assumed to correspond to AFSARCs.

[g]31 December 82 SAR; IOC date from 31 December 83 SAR; (both from DE line): This was the initial SAR and reflects the FSD baseline plan at the time of DSARC II.

[h]Acquisition Plan, April 1984: In January 84, an AF program review was held in place of the planned (February 84) AFSARC for exercise of production option I, which was deferred and the JSPO was instructed to return in April 84 with a revised plan for FSD completion and production milestones. DSARC III date reflects pilot production go-ahead (DSARC IIIA). Budget availability caused at least part of the delay. The June 86 first delivery date corresponds to the 54 month FSD phase at the time of contract award in December 81.

[j]31 September 85 SAR (CE line): *Changes reflect program restructuring from August 85 OSD program review directed by SECDEF and result from less than planned progress from contractor during FSD and Congressional FY86 budget cut.* FSD was extended from 54 to 79 months from the previous plan (DSARC II baseline) with a June 89 IOC (from GAO/NSAID-87-78, March 87). ASARC III (long lead Lot I) is now a program review for approval of Lot I low rate initial production. Production long lead for Lot I is a new item in the SAR. The June 88 first delivery date is based on extrapolation of the 25 month FSD extension.

[k]31 December 86 SAR: DSARC IIIa now JRMB IIIa. Lot I advance buy/long lead contract awards, Lot I full go-ahead, and IOC were delayed 3-4 months because of missile quantity reduction and late approval of FY87 budget by Congress.

[m]31 December 87 SAR and DMS July 87: JRMB is now called the DAB. Slip in Milestone IIIa (April to June 87). Flight test delayed because of technical problems with drones and software problems in missile. Delay in the release of the manpower package to Congress caused a slip in Lot I contracts (July to October 87), causing 3 month delay in first delivery.

the latest estimate of first production delivery, the actual program length was 118 months, a difference of 37 months.[2] This section briefly describes the reasons for this deviation.

Phase I

The AMRAAM schedule approved at DSARC I in November 1978 envisioned a 33 month validation phase beginning with FFP competitive prototype contract awards to two contractors. Contract award was planned for January 1979 with completion of the phase in 1QFY82. Contracts were actually awarded in February 1979 for the 33 month validation phase: Hughes received a $45.4 million contract and Raytheon received $39.1 million. The contracts included proof of concept tasks (16 prototypes each, ten from each contractor to be flight tested)and the concept of leader/follower production. The phase was to be complete in November 1981, at which time DSARC II was to take place and the FSD contract was to be awarded.

According to GAO, the contractors were already five weeks behind schedule by July 1979. First flights of the prototypes occurred in June 1980. Validation phase flight testing fell behind schedule because of technical immaturity, late hardware deliveries, and poor weather. In August 1980, both contractors began to express concern regarding the 40 month FSD phase, which was to follow. Ultimately, the Air Force flight tested only five Raytheon and three Hughes missiles instead of the planned ten each. Because of the operational urgency associated with the program, the Air Force decided to end the validation phase on schedule in November 1981, leaving some design, development, and testing work for the FSD phase.

Because of the concern expressed by the contractors regarding a 40 month FSD phase with IOC in September 1985 as planned at contract award, the JSPO was unable to obtain realistic bids from the two contractors. The JSPO eventually lengthened FSD to 50 months with an August 1986 IOC. The FSD contract award went to Hughes in December 1981. The contract included initial production options for 20 verification missiles, 100 pilot production, and 480 low rate production missiles. DSARC II was planned for November 1982, with release of funds for long lead items for Lot I in October 1983 and the exercise of the first production option in 3QFY84. First production delivery was scheduled for August 1985.

[2]For purposes of measuring schedule intervals in months, the midpoint of a date given in fiscal year quarters was used. For instance, Table C.1 cites a 4QFY85 date for first production delivery. The midpoint of this quarter is August 1985. The interval between November 1978 and August 1985 is 81 months.

Phase II

Figure C.1 shows the evolution of the AMRAAM program schedule for selected milestones. The horizontal axis gives the program schedule, and the vertical axis gives the date when an event affecting the schedule was documented. This was usually soon after the event itself. The numbers give the months of slip associated with each event. For the first delivery milestone, the factors affecting the pace of the program are given on the right, with the numbers representing the slip associated with each factor. The figure illustrates the rather large slips in various milestones that took place during FSD.

The FSD phase started in December 1981 with the contract award to Hughes. Soon after, the schedule was revised moderately, though with no effect on first delivery or IOC. DSARC II was moved up three months (November to August 82) while release of long lead funds was slipped three months (October 83 to January 84). The reasons for this change are not clear. The follower contract to Raytheon was awarded in July 1982.

DSARC II *actually occurred in* September 1982 after a one month slip. The Secretary of Defense Decision Memorandum formally authorizing FSD was issued in November. A new FSD baseline appears to have been established at this time, coinciding with publication of the program's first SAR in December. Long lead funds for Lot I were to be released 2QFY84, a one month slip if the midpoint of the quarter is used. The exercise of production option for Lot I was to be February 1984, and IOC was planned for 4QFY86.

In January 1984, the Air Force held a program review in place of the planned AFSARC (February 84) for exercise of the production option for Lot I, but it was deferred, and the JSPO was instructed to return in April with a revised plan for completion of FSD tasks and the start of production. Concerns regarding increasing cost growth, budget availability, and technical difficulties led to this restructure. The restructured program included a pilot production go-ahead (DSARC IIIa) planned for November 1985, and a first delivery planned for June 1986, a 10 month slip (August 85 to June 86). Technical difficulties and budget availability were cited as the reasons. IOC was rescheduled for November 1987.

Additional technical difficulties relating to sophisticated test equipment, software development, and integration problems, as well as additional cost growth, caused the Secretary of Defense to direct a program review in January 1985. As a result, the AMRAAM FSD phase was extended from 54 months with a June 1986 first delivery to 79 months with a June 1988 first delivery. IOC was slipped to 3QFY89. The

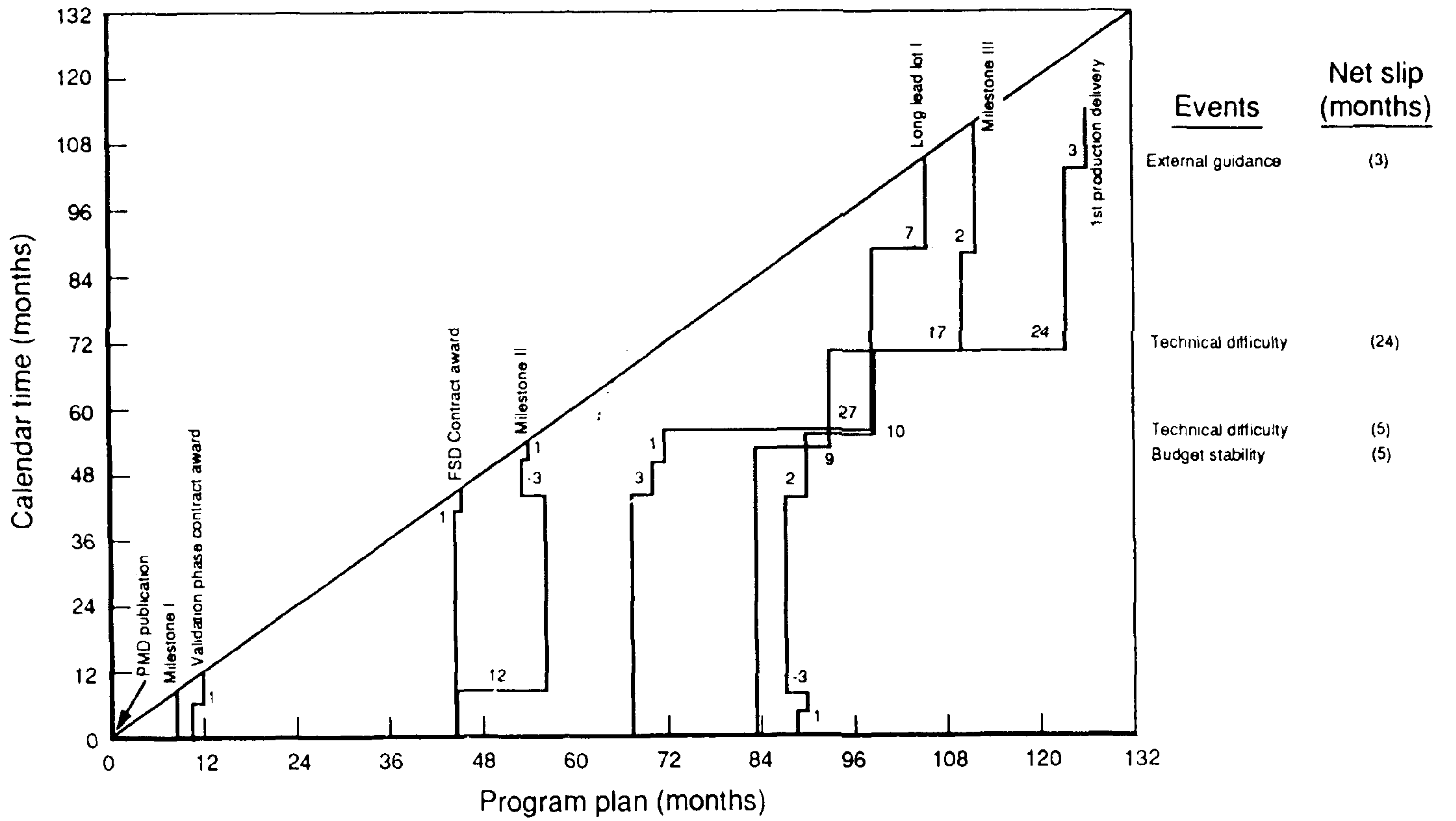

Fig. C.1—AMRAAM schedule evolution

previously negotiated production options were never exercised. These changes were approved by an August 1985 OSD program review. Technical difficulty due to hardware/software integration problems and the change in design associated with changing from solid-state transmitters to traveling wave tubes, and slow contractor response to these problems, appears to be the cause of this restructure. The previously planned AFSARC for release of Lot I long lead funds was changed to a program review for approval of Lot I production and scheduled for 3QFY86. Production long lead for Lot I became a new milestone and was scheduled for about the same time (July 1986). This is perhaps the most major program restructure experienced by AMRAAM, and it generated much concern in Congress. The FY86 Authorization Act required that the Secretary of Defense certify that

- AMRAAM design is complete.
- System performance has not been degraded from original specification.
- The maximum number of cost reduction changes have been incorporated.
- A fixed price contract of $556,580,480 for RDT&E (FSD) has been awarded.
- Total production cost for 17,000 missiles will not exceed $5.2 billion.
- Missiles procured will perform in accordance with development specifications.

The Secretary of Defense provided certification of these items on 28 February 1986.

By the end of 1986, the program had incurred some additional schedule slip for several interim milestones. Lot I advanced buy/long lead contract awards, Lot I full go-ahead, and IOC slipped 3–4 months due to a reduction in missile quantity and late approval of the FY87 budget by Congress. Additionally, DSARC IIIa was changed to JRMB IIIa and slipped two months (April to June 87) because of delays in flight testing and technical problems with target drones and AMRAAM software.

Milestone IIIa approval (now called the DAB) occurred in June 1987 after successfully fulfilling the so called "Congressional 2-shot" test. However, the production contract award for Lot I was delayed three months (July to October 87) because of a delay in the release of the required manpower package to Congress. This also delayed first production delivery by three months (June to September 88).

SUMMARY

Table C.2 summarizes the factors affecting both the original plan and the slip in first production delivery for AMRAAM. The original AMRAAM schedule was 81 months from DSARC I until first production delivery. Using the most current estimate of first delivery, the actual total program length was 118 months, a deviation of 37 months. This is a slip equal to 45 percent of the original plan. While we were unable to account for every slip in every milestone shown in Fig. 1, we were able to account for the entire 37 month slip in first delivery.

The original plan appears to have been affected by seven factors. Competition, prototyping, and the joint management nature of the program seem to have contributed to making the plan longer than it otherwise might have been. These three factors were an integral part of the proposed plan for AMRAAM as early as the October 1976 PMD during the concept exploration phase. At that time, the program length was approximately 90 months. However, external direction to shorten the program by adding concurrency, the high service priority given

Table C.2

FACTORS AFFECTING PACE—AMRAAM

	Original Plan	Deviation from Plan
Competition	L	
Concurrency	S	
Funding adequacy		
Prototype phase	L	
Separate contracting	S	
Service priority	S	
External guidance	S	3 (Delay in manpower package)
Joint management	L	
Program complexity		
Technical difficulty		24 (Software, integration, testing)
Concept stability		
Contractor performance		
External event		
Funding stability		5 (Availability)
Major requirements stability		
Program manager turnover		
Total accounted for		37
Unknown		(+3, −3)
Total slip to first delivery		37

AMRAAM because of TAC's urgent operational requirement, and including production options in the FSD contract contributed to a shorter plan at the time of DSARC I. Though we cannot estimate the relative importance of these factors, or assign particular months of program plan to each, there is some evidence to suggest that these latter factors are responsible for shortening the program as approved at DSARC I from approximately 90 months to 70 months.

First production delivery slipped 37 months (August 85 to September 88). The dominant reason appears to be technical difficulties relating to integration of missile components, software development, and various testing program problems (sophisticated test equipment, target drones). The technical difficulty was in part caused by changing from solid-state transmitters to traveling wave tubes (necessitating a design change) and slow contractor response to technical problems. While budget stability, and bureaucratic hurdles played a role, it is generally believed that underestimation of technical risks at the beginning of the program was the most important factor affecting the pace of AMRAAM.

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Appendix D

AH-64 (APACHE) PROGRAM

This appendix briefly summarizes the factors affecting the pace of the AH-64 Apache program, a twin engine attack helicopter with antitank, antiarmor, and escort roles. The Apache is an integrated weapon platform, consisting of the engine/airframe combination, a 30mm cannon, the Hellfire missile, and the Target Acquisition Designation Sight/Pilot Night Vision Sensor (TADS/PNVS). The information contained here comes from various sources, including public literature, program documentation, and interviews with program office personnel.

BACKGROUND

The Advanced Attack Helicopter (AAH) program was an outgrowth of the Army's search for an improved attack helicopter for almost a decade before program initiation in September 1972. In 1963, the Army began exploring concepts for a new attack helicopter, and a contract was awarded to Lockheed in March 1966 for ten prototypes. This was the Cheyenne and was in response to the Army's Advanced Aerial Fire Support requirement, which emphasized high speeds and an escort role. However, because technical problems resulted in cost growth and schedule slip, and in the anticipation of high production and support costs, the Cheyenne was terminated in August 1972. At the same time a new requirement was formulated for the AAH, based on considerable study and operational experience with armed helicopters in Vietnam. This new requirement downplayed the escort mission in favor of a smaller, more maneuverable aircraft with antitank and antiarmor missions. This included relaxing speed, payload, ferry range, and navigation and gun accuracy requirements, but greater agility and hover performance.[1] The AAH was to be a highly agile, fully integrated aerial weapons platform.

The Apache is managed in a program office in the Army's Aviation Systems Command (AVSCOM). The basic requirement for the AAH is a highly maneuverable attack helicopter for antitank, antiarmor, air cavalry, and armed escort missions, 24 hours per day, and in adverse weather conditions.

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[1]AAH Procurement Summary, 3 December 1976.

The Apache (AH-64A) is a twin engine (T700-GE-701) helicopter with a four bladed rotor. The pilot is located in the rear seat and the copilot/gunner in the forward seat. Armament includes a 30mm cannon, the Hellfire and TADS/PNVS systems, and in some configurations, 2.75 inch folding fin aerial rockets.

ORIGINAL PLAN

The requirement for the AAH was approved at a September 1972 DSARC I meeting, and RFPs were issued in November. The original plan envisioned a six year development effort. The acquisition strategy called for three phases. Phase I (contract award to DSARC II) was to be a 36 month competitive prototype development focusing on the engine/airframe combination; Phase II (DSARC II to DSARC III) was a 36 month FSD effort involving integration of the subsystems; and Phase III was production.

The Phase I contract was awarded in June 1973 to Hughes Helicopter and Bell Textron for competitive prototype development. The contract called for development, fabrication, and testing (both contractor and competitive government testing) of one ground test vehicle and two flying prototypes from each contractor. First flight of the prototypes was scheduled for March 1975, with the flyoff complete 12 months later. The DSARC II decision was planned for May 1976. At program initiation, a design-to-cost goal of \$1.4–\$1.6 million per vehicle was established.

The RFP for Phase I was a mix of specific and functional requirements, with four basic detailed specifications (speed, climb rate, firepower, and endurance) and an additional list of functional requirements. Tradeoffs were allowed above the four "floor" requirements, and cost and schedule goals were given. Phase I focused on the engine/airframe/gun combination and was planned as a competitive prototype phase from the start. The prototyping policy of the time (Deputy Secretary Packard's "fly before buy" policy) may have influenced the decision to prototype, but helicopter firms stated that prototyping was a commonly accepted method in helicopter development. Helicopters are subject to vibration and stability problems that cannot be fully discovered and resolved through wind tunnel testing.

Phase II was planned to begin May 1976 at the DSARC II decision milestone. This phase was to be FSD of the AAH with a single contractor. Three more prototypes were planned for this phase, and the two flying prototypes of Phase I were to be modified to FSD standard for flight testing. Phase II was to be a three year effort focusing on integration of the weapon systems, particularly the TOW missile. The FSD contract award was scheduled for the same month as the DSARC II decision, with a low rate initial production and long-lead-time-item contract planned for April 1978. DSARC III, the full rate production decision, was planned for April 1979, marking the beginning of the production phase. First operational delivery was planned for April 1980.

Overall, the program was perceived as low risk. Medium weight attack helicopters had been part of the inventory for some time and the TOW had already been installed on a helicopter platform (the AH-1). Both firms involved in Phase I had experience with helicopter development. The engine for the AAH was already under development as part of the UTTAS (UH-60) program, which started a year earlier. Additionally, much experience was gained during the development of the Cheyenne.

Five issues stand out as driving the original plan. The inclusion of a prototyping phase, separate from FSD, obviously had a substantial effect on the planned program length, as time must be allowed for government testing and evaluation. Making this a competitive prototype phase also may have contributed to program length, but it is difficult to tell whether this added time to the plan. Cost considerations may have limited both the duration of the competition and the number of firms and prototypes involved, though the program seems to have been adequately funded. Additionally, there was no concurrency in the original plan.[2] The three phases were planned to be distinct, with progression to the next phase dependent on results from the previous phase. Other factors that may have affected the original plan include a high service priority and the separate contracting implied by the sequential acquisition plan. We were unable to determine the relative effect of these factors on the planned program length, but the competitive prototype phase and the acquisition strategy implied were apparently the main factors.

EVENTS AND DEVIATIONS

Table D.1 shows selected schedule milestones for the Apache program. The dates under the revised plan columns give the date at which program schedule changes occurred. As one can see, there were many program changes throughout the life of the program. The original plan, measured from DSARC I to first operational delivery was 91 months. The total actual program length was 136 months, a deviation of 45 months.

[2]G. E. Morrow, C. Lowe, and E. H. Birdseye, *Lessons Learned—Advanced Attack Helicopter*, Defense Systems Management College, July 1983, p. 14.

Phase I

Phase I seems to have been fairly smooth. Contract awards to Bell and Hughes for competitive prototypes (the YAH-63 and YAH-64 respectively) occurred as planned in June 1973. However, in February 1975, cost growth due to an unexpectedly high inflation rate caused a six month slip in the schedule, which seems to have affected all down-stream milestones. The first flights of the prototypes occurred six months late in September 1975, instead of March 1975 as originally planned. The new deadline for delivery to the Army for competitive testing, May 1976, slipped slightly because one Bell prototype crashed and both contractors experienced technical difficulties. However, the slip was only marginal and the flyoff ran smoothly and ended on the revised schedule date in September 1976.

The actual length of Phase I, measured from contract award to DSARC II, was 42 months rather than the 36 months originally planned. The unanticipated inflation that caused cost growth seems only to have affected the schedule and not Phase I activities. However, several changes were made to the program toward the end of Phase I that resulted in a 19 month extension to Phase II, although they did not affect Phase I activities.

Phase II

Figure D.1 shows the evolution of the schedule for various mile-stones. The horizontal axis gives the program schedule, and the vertical axis gives the date in which program changes occurred. For the Apache, most of the changes in milestones were reflected in down-stream milestones. The numbers on the figure give the months of slip associated with each event. For the first delivery milestone, the factors affecting the pace of the program are listed on the right, with the numbers representing the slip associated with each factor.[3]

In July 1975, Congress deleted the FY75 request for prototype development long lead items for Phase II. Congress seemed to feel that the money spent by the losing contractor in the competition would be wasted. This funding deletion resulted in a five month delay during fabrication of the Phase II prototypes.

Several requirements changes occurred at the end of Phase I regarding armament. In February 1976, the Army decided to replace the

[3]Note that the months of slip associated with each factor do not correspond exactly with the periods of slip in Fig. D.1 because of an overlap across some slip periods for some factors. However, the sum of the total slip assigned to each factor equals the total program slip. The allocation of months of slip to each factor received program office concurrence.

Table D.1

AH-64 (APACHE) MILESTONE TABLE

Milestone	Original Plan (Sep 72)	Revised Plan[a] (Feb 75)	Revised Plan[b] (Jul 75)	Revised Plan[c] (Feb 76)	Revised Plan[d] (Mar 76)	Revised Plan[e] (Oct 76)	Revised Plan[f] (Dec 76)	Revised Plan[g] (Feb 77)
DSARC I	Sep 72							
RFP release	Nov 72							
Contract award (Phase I)	June 73							
Prototypes 1st flight	Mar 75	Sep 75						
F/O complete	Mar 76	Sep 76	Sep 76	Sep 76	Nov 76	Sep 76		
DSARC II	May 76	Nov 76	Nov 76	Nov 76	Nov 76	Dec 76	Dec 76	
Contract award (FSED)	May 76	Nov 76	Nov 76	Dec 76	Jan 77	Dec 76	Dec 76	
LRIP/LLTI contract	Apr 78	Oct 78	Mar 79	Mar 80	Mar 80	Jun 80	Jun 80	Jun 81
DSARC III	Apr 79	Oct 79	Mar 80	Sep 80	Sep 80	May 80	May 80	May 81
Operational test II complete				Sep 80	Aug 80	Aug 80	Feb 81	Dec 81
Contract award (production)	Apr 79	Oct 79	Mar 80	Sep 80	Sep 80	Oct 80	Oct 80	Oct 81
1st production delivery	Apr 80	Oct 80	Mar 81	Jun 82	Jun 82	Jun 82	June 82	Jun 83
FUE/IOC	Oct 80	Apr 81	Sep 82	Mar 83	May 83	May 83	May 83	May 84

NOTES: Data for this table were provided by SPO personnel in approximately this format. Sources were various program documentation and Selected Acquisition Reports.

[a]Leadtime funding and cost escalation resulted in six month extension to Phase I.

[b]FY76 and FY77 deletion of prototype development lead time item funding caused five month extension of Phase II.

[c]Decision to replace TOW with Hellfire resulted in five month slip in Phase II.

[d]Need to replace TOW Optics with TADS/PNVS for Hellfire and change in 30mm ammunition to NATO standard resulted in four month Phase II delay.

[e]Phase II five month extension to allow modification of AAH prototypes with TADS/PNVS and correction of Phase I deficiencies.

[f]DSARC II baseline schedule. OT II changed because of inclusion of Hellfire and TADS/PNVS.

[g]50 percent budget cut by OSD for FY78 ($100m) resulted in ten month slip.

Table D.1—continued

Revised Plan[h] (Nov 77)	Revised Plan[j] (Sep 72)	Revised Plan[k] (Feb 75)	Revised Plan[m] (Jul 75)	Revised Plan[n] (Feb 76)	Revised Plan[p] (Mar 76)	Revised Plan[q] (Oct 76)	Revised Plan[r] (Dec 76)	Revised Plan[s] (Feb 77)
								Sep 72
								Nov 72
								Jun 73
								Sep 75
								Sep 76
								Dec 76
								Dec 76
—	Feb 81	Feb 81						Feb 81
Nov 80	Nov 81	Dec 81	Dec 81	Mar 82				Mar 82
Aug 81	Aug 81	Aug 81	Aug 81					Aug 81
Dec 80	Dec 81	Dec 81	Dec 81	Apr 82				Apr 82
Dec 82	Nov 83	Dec 83	Nov 83	Feb 84	Jan 84			Jan 84
Nov 83	Oct 84	Jan 85	FY85	FY85	FY85	Apr 86	Aug 86	Jul 86

[h]Partial budget restoration by Congress ($65m) for FY78. As contract had already been renegotiated, proportional recovery was not possible. Recovered four months.

[j]Lead times from 18 to 36 months.

[k]Restructure support/training and combine slit OT II into single OT.

[m]Nov 81 SAR.

[n]Mar 82 SAR.

[p]Dec 83 SAR.

[q]Dec 84 SAR.

[r]Full unit equipped (FUE) adjusted for training/fielding.

[s]Actual dates, Dec 86 SAR.

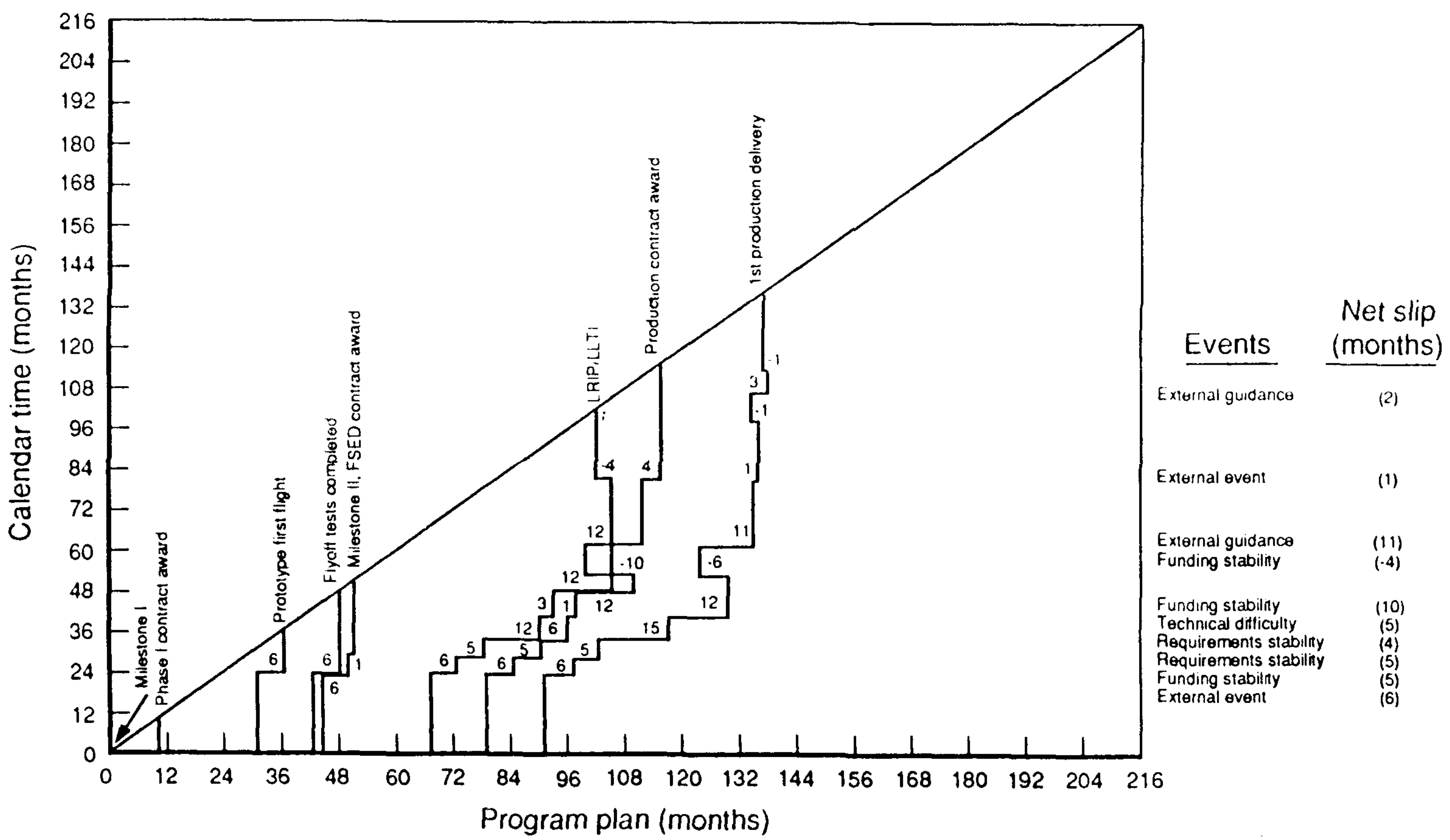

Fig. D.1—AH-64 Apache schedule evolution

TOW missile with the Hellfire, a laser guided missile then under development designed specifically for helicopters. Though Hellfire development started at about the same time as the Apache program, it was decided at the time to install TOW in the initial production Apaches and modify the production vehicles later as Hellfire became available. This decision was reversed. Because the TOW optical sight was incompatible with the Hellfire, in March 1976 the Army announced the addition of TADS/PNVS. This was a targeting and pilot sensor system designed for the Hellfire. While Hellfire was a separate program, TADS/PNVS was run as a subprogram in the Apache SPO, using SPO funding. The addition of the Hellfire resulted in a five month extension to Phase II, and TADS/PNVS added another four months and tied a fairly low risk airframe development to somewhat higher risk subsystems, increasing the overall risk of the program. In September 1976, the Army decided to change the 30mm ammunition to a NATO standard. While not adding more time to the schedule, it was an important requirement change.

The last event, which occurred during Phase I but affected Phase II, was an October 1976 decision to extend Phase II by 5 months. This decision was taken to allow the winning contractor additional time to correct technical deficiencies uncovered during Phase I testing. In December 1976, Hughes was selected to proceed into full scale development.

Events at the end of Phase I added 19 months to the program schedule, in addition to the Phase I six month extension. The schedule at DSARC II in December 1976 envisioned the low rate initial production/long lead time items (LRIP/LLTI) contract award in June 1980, DSARC III in May 1980, and first production delivery in June 1982. The interesting thing about these changes was that they were reflected almost identically in downstream milestones.

Two funding stability events related to FY78 funding levels affected the Phase II schedule. In January 1977, the new Secretary of Defense directed that the Apache budget request for FY78 be reduced by 50 percent ($100 million). The issue concerned the overlap in missions between the Apache and the Air Force A-10. This budget cut resulted in a ten month slip in completion of Phase II and a 12 month slip in production start. However, in July 1977, the Army was able to persuade Congress to reinstate $65 million in FY78 funding. Because of the renegotiated contract, which extended development by ten months, the Army was not able to recover the schedule in direct proportion to the funding recovery: four months were recovered in Phase II.

In July 1979, external guidance regarding lead time items slipped the DSARC III and production contract award milestones by 12 months

(November 80 to November 81 and December 80 to December 81 respectively), and the first production delivery by 11 months (December 82 to November 83). A November 1980 crash of one of the five FSD prototypes resulted in a one month delay in DSARC III as the remainder of the test program was allocated across the other four prototypes. After investigation, the crash was determined to be nonsystem-related. DSARC III was delayed an additional three months (December 81 to March 82) to allow completion of the test program and provide the DSARC with better information to allow a full rate production decision. The production contract and first delivery both slipped four months as a result. DSARC III took place in March 1982, with the production contract award the following April. Although first production delivery was scheduled for February 1984, it took place one month early in January.[4]

SUMMARY

Table D.2 presents a summary of the factors affecting the pace of the Apache program. The total planned length of the program, from DSARC I to first operational delivery, was 91 months. The total actual program length was 136 months, a 45 month slip or almost 50 percent of the original plan. Although we were unable to account for every month of slip in each milestone shown in Fig. D.1, we can account for the entire 45 month slip in first delivery.

The length of the original plan seems to have been most influenced by the incorporation of a competitive prototype phase as part of the acquisition strategy. Originally planned for 36 months but actually taking 42 months, the prototyping phase incorporated the design, development, fabrication, and testing of the two Apache designs. The competitive test itself was four months, from May to September 1976. The separate contracting implied by this strategy also may have affected the original plan. The lack of concurrency between development and production was a built-in feature of the original acquisition strategy and probably contributed to the initial program length. Funding constraints appear to have reduced the scope of the Phase I effort, but the tasks that were planned seem to have been adequately funded. Unfortunately, available information does not allow a close association between these factors and portions of the original plan.

The events causing deviations from the original plan are quite varied, with no dominant factor. External guidance, requirements

[4]In 1984, Hughes Helicopter was purchased by McDonnell Douglas Helicopter Company.

Table D.2

FACTORS AFFECTING PACE—AH-64 APACHE

	Original Plan	Deviation from Plan
Competition	L	
Concurrency	L	
Funding adequacy	S	
Prototype phase	L	
Separate contracting	L	
Service priority		
External guidance		11 (long lead approval) 2 (delay in DSARC III)
Joint management		
Program complexity		
Technical difficulty		5 (in Phase II)
Concept stability		
Contractor performance		
External event		6 (cost growth due to inflation) 1 (crash)
Funding stability		5 (long lead delay in Congress) 10 (budget cut) −4 (partial budget restoration)
Major requirements stability		5 (Hellfire) 4 (TAD/PNVS)
Program manager turnover		
Total accounted for		45
Unknown		0
Total slip to first delivery		45

changes, and funding stability are the major causes of schedule slip, accounting for about 30 percent, 20 percent, and 25 percent respectively of the total slip. The requirements changes came early in the program and were unrelated to the results of the prototyping phase, but the external guidance changes occurred fairly late in the program. In fact, only about 11 percent of the schedule slip (in Phase II) was due to technical changes made as a result of prototype testing. The funding changes also occurred early in the program. About 15 percent of the slip in first delivery was due to external events.

Although there was considerable Congressional interest in the program throughout, particularly because of the perception of a cost growth problem, this did not seem to affect the pace of the program very much. In the case of the Apache, program stability factors (guidance, funding, requirements) dominate the pace of the program and together account for almost 75 percent of the slip in first operational delivery.

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Appendix E

DIVISION AIR DEFENSE GUN (DIVAD)

This appendix briefly describes the factors affecting the pace of the Division Air Defense Gun System (DIVAD) program. DIVAD is a twin 40mm radar directed antiaircraft gun mounted on an M48 tank chassis. Its three main components—the 40mm Bofors guns, the radar (a derivative of the F-16 radar), and the chassis—are all mature, though previously used in other weapon systems. The information presented here comes from various sources, including public literature, program documentation, and interviews with program office personnel.

BACKGROUND

Studies on new air defense guns began as early as 1962. The Army's only existing air defense gun was the Vulcan, a 20mm twin cannon thought to be ineffective against the growing threat of armored CAS aircraft. Formal DIVAD studies were completed in August 1975, at which time the Vice Chief of Staff directed that a required operational capability (ROC) document be developed. In July 1976 an ASARC/DSARC "0" directed advanced engineering development for the DIVAD; however, no hardware was fabricated and tested at that time. The ROC was approved in August 1976 for a radar directed air defense gun. As early as October 1976, the Department of the Army and DARCOM (as the Army Materiel Command was called at the time) approved a dual engineering approach. Throughout this period, several studies were performed comparing the effectiveness of guns and surface-to-air missiles in the air defense role. Operational experience with SAMs tended to support the concept of an air defense gun and contributed to the high service priority of DIVAD. By the time the DIVAD program was formally initiated (at DSARC I in February 77) it had been 15 years since the Army developed a new air defense gun.

The DIVAD program was managed in a program office in DARCOM (later the Army Materiel Command). The DIVAD was to be used in the forward area of a land battle and travel with the tanks and armored infantry vehicles it was designed to protect.

The DIVAD is an all weather, radar directed, twin 40mm cannon air defense gun mounted on an M48 tank chassis with an eight second response time (target acquisition to fire). It is operated by a crew of three: gunner, driver, and squad leader. Use of mature subsystems was an integral part of the acquisition strategy. The winning system (designed by Ford Aerospace) used 40mm Bofors guns, a derivative of the F-16 radar (a modified Westinghouse APG-66), and an existing tank chassis (the M48 chassis was provided to the contractors as government furnished equipment). The DIVAD concept included slaving the guns to the radar system and making the system mobile and armored. Integration of these mature subsystems into a functional weapon system was identified as the major technical risk. The basic threat to which DIVAD was addressed included air defense against low level close air support aircraft to a range of 4 km. Originally, the DIVAD was to focus on fixed wing aircraft, but the development of attack helicopters added a new dimension to the mission.

ORIGINAL PLAN

The acquisition strategy for the DIVAD program is a direct response to concerns about the purportedly lengthening acquisition time of new weapon systems. In response to Congressional direction, the Army initiated an "accelerated acquisition strategy" for the DIVAD, designed to cut program length (from initiation to IOC) in half relative to other contemporary systems.

Elements of the accelerated strategy included:

- Parallel competitive development.
- A "skunk works" management policy.
- A short DT/OT phase following development.
- Use of mature subsystems.
- A maturity phase following development, which included follow-on development and initial production.

The parallel competitive development included "prototyping for production" by two contractors. The "skunk works" policy, based on Air Force experience with Lockheed, involved minimal government management and flexible requirements tradeoffs, with considerable contractor latitude. These elements combined to make the original DIVAD program a highly compressed, concurrent strategy. The strategy was known to involve risks, but several elements were included to minimize these risks. Use of mature components was to reduce technical risks to basically just an integration challenge. The competitive development contract was to be fixed price (best efforts) and the maturity/initial production contract also was to be fixed price with three fixed pre-priced production options and a warranty provision making the contractor responsible for fixing production units up to 90 days after delivery at no cost to the government.

DSARC I occurred in February 1977. At that time, the formal acquisition strategy was approved, including open competition and the accelerated strategy described above. In April, RFPs were released to industry that included 12 firm requirements (e.g., NATO commonality, 30–40mm gun, mature components, M48 tank chassis) and 43 cost/performance tradeoffs. The program plan at this time included contract awards to two contractors in November 1977 following a DSARC II meeting. Each contractor was to build two prototypes for delivery in June 1980, at which time a three month shootoff would commence. Source selection and the maturity/initial production contract award were planned for October 1980 with the exercise of the first production option planned for May 1981 and first production delivery in June 1982. IOC was scheduled for October 1983.

The competition and prototyping characteristics appear to have influenced the original plan by making it somewhat longer. However, because this phase was competitive *development* and not *demonstration/validation*, the tendency of these factors to increase program length was outweighed by the high degree of concurrency in the program. The concurrency is indicated by the "maturity phase," which combined follow-on development with initial production. The high service priority attributed to the DIVAD and direction to use an accelerated acquisition strategy influenced the original plan to be shorter than other contemporary programs.

EVENTS AND DEVIATIONS

Table E.1 presents selected schedule milestones for the DIVAD program. The dates under the revised plan columns are when an event that affected the program schedule was documented. The original plan, measured from DSARC I to first production delivery, was 64 months. The actual total program length was 85 months, a slip of 21 months in the delivery of the first production unit.

Five contractors responded to the RFP in July 1977.[1] The DSARC II meeting occurred as planned in November 1977 (a very short, nine month "phase I"), but contract award was delayed to answer several questions raised by the Cost and Operational Effectiveness Analysis (COEA) at the DSARC. The competitive development contracts were

[1]Ford Aerospace, General Dynamics, Sperry Rand, Raytheon, and General Electric.

Table E.1

DIVAD MILESTONE TABLE

Milestone	Original Plan[a] (Mar 78)	Revised Plan[b] (Mar 79)	Revised Plan[c] (Jun 79)	Revised Plan[d] (Sep 79)	Revised Plan[e] (Dec 79)	Revised Plan[f] (Jun 80)	Revised Plan[g] (Sep 80)	Revised Plan[h] (Mar 81)	Revised Plan[j] (Jun 81)	Revised Plan[k] (Jun 82)	Revised Plan[m] (Dec 83)	Revised Plan[n] (Dec 84)	Actual Plan[p] (Sep 85)
DSARC I	Feb 77												Feb 77
DSARC II	Nov 77												Nov 77
Engineering development contract award	Jan 78												Jan 78
Prototype delivery	Jun 80												Jun 80
DT/OT II													
Start	Jun 80												Jun 80
Complete	Sep 80						Nov 80						Nov 80
DSARC III	Oct 80				Nov 80	Sep 81	Dec 81	Mar 82	Apr 82	May 82			May 82
ILS development and test													
Start	Oct 80					Dec 80	Feb 81	Apr 81	May 81				May 81
Maturity and check test (contingency)	Oct 80					Dec 80	Feb 81	Apr 81	May 81				May 81
IP contract award	Oct 80				Nov 80	Dec 80	Feb 81	Apr 81	May 81				May 81
Tech data package delivery	Aug 81	Feb 83			Oct 83	May 84		Sep 84	Oct 84			Sep 85	Sep 85
1st production equipment delivery	Jun 82				Dec 82	Apr 83		Aug 83	Sep 83		Feb 84	Mar 84	Mar 84
Initial production test													
Start	Jul 82			Oct 82	May 83	Nov 83		Mar 84	Apr 84			Oct 84	Oct 84
Complete	Jan 83			Mar 83	Nov 83	May 84		Aug 84	Sep 84			Mar 85	May 85
Program termination													Aug 85**
Follow-on production contract award	Oct 82		Jul 83		Oct 84	Nov 84		Mar 85	Apr 85			Jan 86	
IOC	Oct 83					Oct 84		Jan 85	Mar 85			Mar 87	
Follow-on production test													
Start	Jun 84		Mar 85		Mar 86	May 86		Sep 86	Oct 86			Jun 87	
Complete	Nov 84		Aug 85		Aug 86	Oct 86		Feb 87	Mar 87			Sep 87	
Production complete	Aug 87				Oct 87	Sep 88		Jan 89	Feb 89			Jun 90	

Table E.1—continued

[a]From April 78 SAR, Development Estimate. This was the initial SAR. Program reflects a 29 month engineering development effort followed by a 3 month DT/OT (including a competitive shootoff). Selected contractor would be awarded an initial production contract, which would include a maturity phase.

[b]April 79 SAR. Technical data package delivery changed because of rescheduling of level 3 TDP to after completion of physical configuration audit.

[c]June 79 SAR. Change in procurement plan: 12 units delivered in FY81 plus options for 72 units and long lead items for FY82.

[d]September 79 SAR. Allows implementation of block changes from RAM growth program at about production unit 13.

[e]December 79 SAR. DSARC III and IP contract award delayed one month based on ASARC/DSARC master schedule. FY81 program was restructured in December 79 to allow for additional leadtime resulting in a six month slip in production schedule.

[f]June 80 SAR. Changes reflect effect of $100m reduction in FY81 program resulting in restructure, which eliminated FY81 buy of 12 units.

[g]September 80 SAR. Prototype hardware was less mature than expected resulting in 60 day extension to DT/OT and IP contract award. DSARC III delayed to allow completion of maturity check test.

[h]March 81 SAR. Changes reflect major program restructure, which occurred before December 80 SAR because of uncertainty regarding future funding levels. December 80 SAR listed all milestones as TBD.

[j]June 81 SAR. Delay of source selection from April to May 81 resulted in one month slip in milestones.

[k]June 82 SAR. DSARC III delayed one month because of personnel scheduling difficulties within OSD. No other milestones affected.

[m]December 83 SAR. 1st delivery delayed because of inadequate deliveries of FACCs in house electronic and mechanical assemblies.

[n]December 84 SAR. TDP delayed to allow completion of IPT and incorporation of changes. IP test delayed because of availability of fire units. IOC was redefined and the production schedule was revised.

[p]September 85 SAR. This was the last SAR submitted after program termination on 27 August 85.

awarded to Ford ($39.6 million) and General Dynamics ($39.1 million) in January 1978 after a two month delay. A 29 month competitive development would culminate with delivery of the prototypes in June 1980 and completion of DT/OT II (the shootoff) in September.

Figure E.1 shows the evolution of the DIVAD program schedule for several milestones. The original plan is read off the horizontal axis, and subsequent changes are reflected in the various curves for each milestone. The vertical axis gives the date when program documentation reflected these changes. Each number represents months of slip associated with a particular event. For the first delivery milestone, the factors affecting pace are given on the right, as well as the number of months of slip associated with each factor.

Although the prototypes were delivered on schedule in June 1980, both designs were unexpectedly immature. This delayed completion of government testing (DT/OT II) by two months until November 1980. Nonetheless, source selection procedures had begun on schedule in August 1980. The delay in completion of DT/OT II also delayed the maturity/initial production contract award by one month (from October to November 80), as well as DSARC III (October 80 to November 80). In November 1979, the FY81 budget request was reduced from $275.2 to $171.6 million, resulting in a restructure of the program. The OSD-directed reduction resulted in reducing FY81 procurement from 42 to 12 units, and resulted in a six month slip in the production schedule. The program plan in December 1979 called for first production delivery in December 1982 rather than the previously planned June 1982 date (six month slip), and an eight month slip in completion of the initial production test (from March 83 to November 83).

In the spring of 1980, an additional $100 million budget reduction for FY81 directed by OSD eliminated FY81 production and resulted in another program restructure, the second major schedule revision before the prototypes were delivered. DSARC III was now planned for September 1981 (a ten month slip), and first production delivery was now planned for April 1983 (a four month slip). Completion of the initial production test was delayed six months (from November 83 to May 84).

In September 1980, the immaturity of the prototypes delivered in June became apparent, resulting in a two month delay in DT/OT II completion and maturity/initial production contract award (as discussed above). DT/OT II was completed in November 1980. However, DSARC III was delayed from September to December 1981 (two months) to allow completion of the maturity check test, a test planned from the outset to evaluate whether shortcomings in the winning contractor's prototypes had been fixed before exercise of the first production option. Previous delays in DSARC III are attributable to the

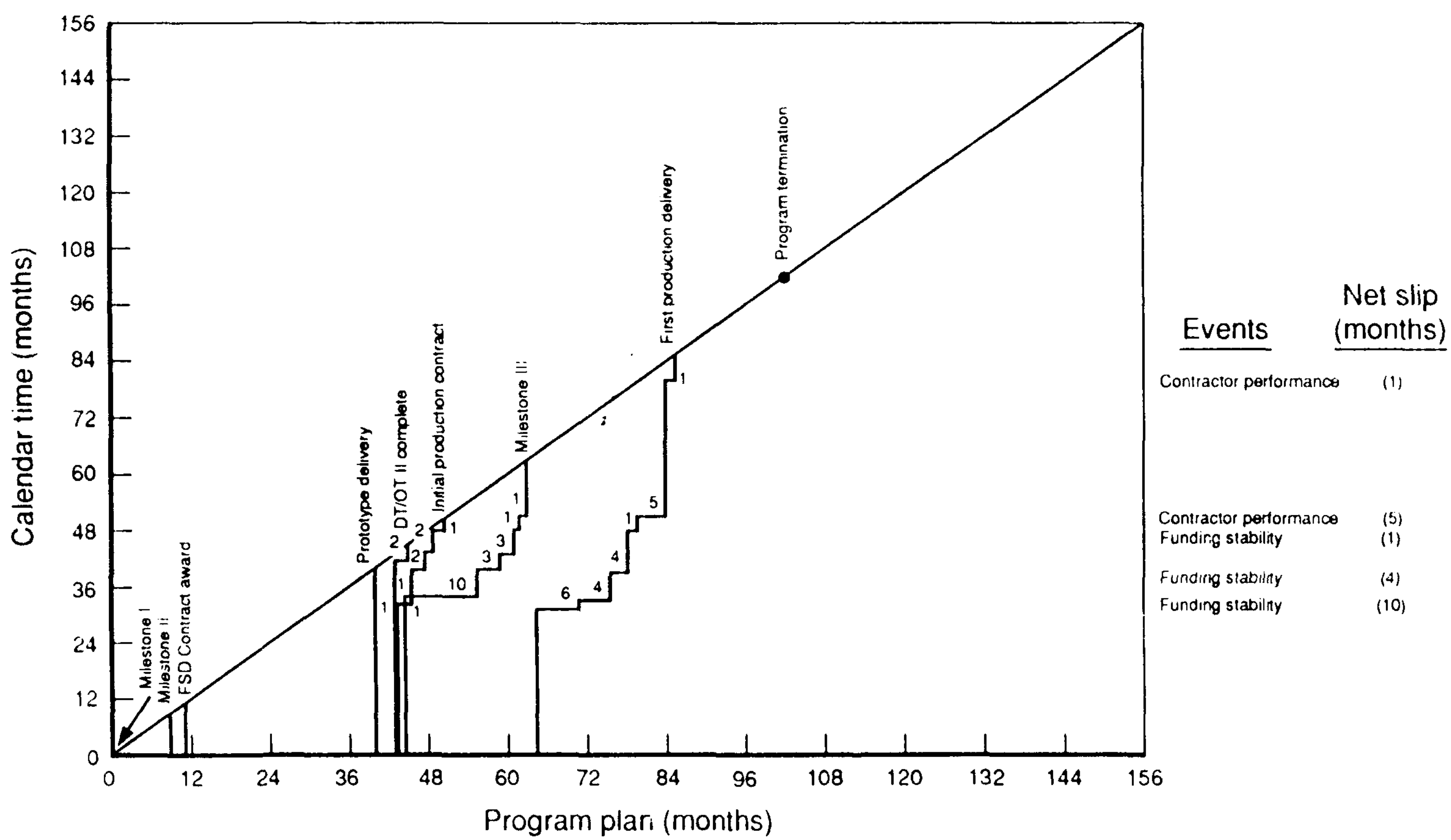

Fig. E.1—DIVAD schedule evolution

desire to allow additional testing before the exercise of the first production option. The maturity/initial production contract was now scheduled for February 1981.

The December 1980 *Selected Acquisition Report* listed all downstream milestones as "to be determined" reflecting major uncertainties in the funding profile of the DIVAD program. By March 1981, a revised schedule had been developed. DSARC III was now planned for March 1982 (a three month slip), the contract for maturity/initial production was now scheduled for April 1981 (a two month slip), and first production delivery was planned for August 1983 (a four month slip). A delay in source selection activities from April to May 1981 caused a one month slip in all downstream milestones (see Table E.1). The maturity/initial production contract was awarded to Ford in May 1981 for $159 million and included a 12 month maturity phase before exercise of the first production option (planned for May 82) and three prepriced annual production options beginning in FY82. The last three months of this maturity phase (December 81 to March 82) included the check test. At the time of contract award, first production delivery was scheduled for September 1983, 15 months later than originally planned.

The Ford prototypes continued to show deficiencies throughout the testing program, and design immaturity continued past the 12 month maturity period. In fact, a reliability and maintainability test (called RAM-D) scheduled to begin in April 1982 had to be canceled because of "wear and tear" on the prototypes, lack of spare parts, and immaturity. The acquisition plan seems to have included a "test-fix-test" approach using the prototypes (each upgraded after testing indicated deficiencies). The RAM-D test was postponed until the initial production test, scheduled to begin in April 1984 using production units from the first lot. These problems appear to have reduced the amount of information available to decisionmakers during the DSARC III process. DSARC III actually occurred in May 1982, after incurring an additional two months of delay for source selection delays and scheduling difficulties of the DSARC participants. The DSARC resulted in approval of the FY82 production option for 50 units.

In December 1983, the DIVAD schedule reflected an additional five month delay in first delivery because of inadequate deliveries of Ford's in-house developed components. The new first delivery date was February 1984 and seems to reflect a combination of technical problems, particularly integration (the cumulative effect over time), and contractor performance. Start-up problems at Ford's production facility delayed first delivery by an additional month to March 1984, the actual delivery date. The program was restructured again around this date, mostly affecting testing and production milestones.

The Army exercised the second production option (FY83) for 96 units in May 1983. However, by this time the program was receiving a great deal of OSD and Congressional attention because of schedule slips, cost growth, and the apparently as yet unresolved technical and operational effectiveness problems. The threat had changed as well: The development of an antitank missile with a 6 km range for the Soviet HIND attack helicopters led to scrutiny of the effectiveness of the DIVAD, which had yet to prove to critics' satisfaction that it could defeat the 4 km helicopter threat it was designed for. In October 1984 the program was slowed down to allow completion of the initial production test and follow-on testing directed by the Secretary of Defense. Option 3 was deferred until after completion of these tests to September 1985. The tests were completed in the spring of 1985, and, after a thorough evaluation, the Secretary of Defense terminated the program on August 27, 1985. The DIVAD is one of the few programs to be canceled by DoD after production had started.

SUMMARY

Table E.2 summarizes the factors affecting the pace of the DIVAD program. The original plan was 64 months, measured from DSARC I to first production delivery. Actual total program length was 85 months, a slip of 21 months or 33 percent of the original plan. Although we were unable to account for every slip in every milestone, we have accounted for the full 21 month slip in first delivery.

The original plan for the DIVAD program was an "accelerated" acquisition strategy because of Congressional direction to shorten the acquisition cycle. The high priority that the Army placed in DIVAD (the existing air defense gun—Vulcan—was 20 years old and no longer effective) and the highly concurrent nature of the schedule also seem to have made the plan shorter than it otherwise might have been. Even *the use of competitive prototyping,* usually held to lengthen acquisition schedules (though there is no unambiguous proof of this) was used differently as part of the "accelerated" approach. The program bypassed a demonstration-validation phase entirely and moved directly into FSD with a competitive parallel development approach. The accelerated strategy seems to have made schedule the dominant consideration in cost/schedule/performance tradeoffs.

Budget instability seems to account for the majority of schedule slip in the DIVAD program. Roughly 3/4 of the slip concerns budget cuts, mostly relating to the FY81 budget and outyear funding. The rest of the slip is attributable to poor contractor performance, particularly

Table E.2

FACTORS AFFECTING PACE—DIVAD

	Original Plan	Deviation from Plan
Competition	L	
Concurrency	S	
Funding adequacy		
Prototype phase	L	
Separate contracting		
Service priority	S	
External guidance	S	
Joint management		
Program complexity		
Technical difficulty		
Concept stability		
Contractor performance		5 (inadequate deliveries of components) 1 (production start-up problems)
External event		
Funding stability		6 (FY81 reduction) 4 (FY81 procurement cut) 4 (FY82 amended budget) 1 (change in administration and new budget)
Major requirements stability		
Program manager turnover		
Total accounted for		21
Unknown		0
Total slip to first delivery		21

startup problems and late deliveries of components for production. Technical problems, which plagued the program throughout its life, appear to have been dominated by these factors, though they may have contributed to the poor contractor performance. The integration challenge associated with the use of mature components was greatly underestimated. In particular, alhtough the hardware already existed, new software had to be developed.

The accelerated strategy, characterized in part by minimal testing before critical decisions, appears not to have been effective in the DIVAD program. One indication of this, aside from the fact that the program was terminated, is changes in the test program. Table E.3 lists the tests associated with the program and indicates that about two-thirds of the tests eventually planned for the DIVAD were added after the original plan had been approved.

Table E.3

DIVAD TEST STRATEGY

Test Type	Time Period	
	Start	Stop
DT/OT II[a]	July 1980	Nov 1980
Check test[a]	Nov 1981	Jan 1982
4000 mile chassis test[b]	Dec 1981	Feb 1982
RAM-D[b]	Feb 1982	Apr 1982
Built in test demo[b]	May 1982, Apr 1983, Oct 1983, Mar 1985, Feb 1986	
Contractor engineering test[b]	Apr 1982	Dec 1982
Engineering prototype test[b]	June 1983	Aug 1983
Publications verification-physical teardown/logistic demo[b]	Sept 1984	June 1985
Design verification[c]	Mar 1984	Nov 1984
Limited tests[c]	July 1984	Aug 1984
Initial production test[a]	Oct 1984	Mar 1985
Follow-on OT&E[a]	Jan 1985	Mar 1985
FOT&E I[c]	June 1985	July 1985
Comparison test[a]	Oct 1985	Mar 1986
Cold region test[b]	Oct 1985	Mar 1986
FOT&E II[c]	Jan 1986	Mar 1986

NOTE: Test-fix-test was the strategy according to Army. The above are DIVAD tests as listed in October 2 1984 SASC Hearings. The listing is not meant to imply that the test actually occurred.

[a]Original test strategy.

[b]Additions prior to DSARC III (May 1982).

[c]Additions after DSARC III.

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Appendix F

F/A-18 HORNET

This appendix briefly describes the factors affecting the pace of the F/A-18 program, a twin engine carrier based aircraft. The F/A-18 is the Navy's first multimission aircraft, with fighter escort, fleet air defense, interdiction, and close air support roles. The fighter and attack versions of the aircraft are identical except for external equipment and ordnance: Both versions are equipped with an internal 20mm gun and wingtip Sidewinder missiles; and the F/A-18 radar has both air-to-air (all weather) and air-to-ground capabilities. The information contained here comes from various sources, including public literature, program documentation, and interviews with program office personnel.

BACKGROUND

The F/A-18 program resulted from the Navy's interest in a dual mission carrier based aircraft with both attack and fighter capabilities. The aircraft was intended as a replacement for the A-7, A-4, and F-4 in fighter and light attack missions, and as a lower cost complement to the F-14. The aircraft was to be the Navy's first dual mission aircraft and was an important doctrinal innovation from the previous concept of separate designs for attack and fighter roles. The Navy formally began the program in April 1974 with the approval of the VFAX requirement for a low cost, lightweight, dual role fighter aircraft. Six firms responded to the Navy's RFP for design studies in June 1974. However, in August 1974, Congress, desiring increased commonality between Navy and Air Force tactical aircraft, directed that the VFAX program be terminated and that the Navy choose one of the Air Force's lightweight fighter prototypes (the YF-16 or YF-17) as the basis for the new aircraft. The Navy promulgated an operational requirement for a dual mission strike fighter in August 1974 (OR-WO4TW), which satisfied the VFAX requirement. In October 1974, the Navy released an RFP as a supplement to the Air Force's lightweight fighter (LWF) program. Subsequent to the Air Force's selection of the YF-16, the Navy selected the YF-17 in May 1975 as the basis for the F/A-18 program. This was somewhat against Congress's wishes, but it was argued that the YF-17 could more easily be modified for carrier operations. Design contracts were awarded the same month.

The F/A-18 program is managed by a system program office in the Naval Air Systems Command. The prime contractor on the program is McDonnell Douglas, with Northrop (the developer of the YF-17) as the major subcontractor. McDonnell Douglas and Northrop split production work 60 percent and 40 percent respectively.

The F/A-18 is a twin engine, dual role aircraft with fighter escort, fleet air defense, interdiction, and close air support missions. The engines are the General Electric F404-GE-400. Both the fighter and attack versions are essentially the same, the only difference being the external equipment and ordnance carried. Both versions have an internal 20mm gun and wingtip Sidewinder air-to-air missiles, and a radar (Hughes APG-65) with both air-to-air (all weather) and air-to-ground capabilities. The F/A-18 contains 9.5 percent composites (carbon/epoxy) by structural weight, or 40 percent of the aircraft's surface area. The differences between the YF-17 and F/A-18 proposed at program start include:

- Increased engine thrust (14,100 lb to 16,100 lb).
- Increased wing area (14 percent).
- Added aerodynamic wing flow fence.
- Missionized avionics.
- Increased structural strength for carrier operations.
- Increased transonic roll rate.
- Increased empty weight (17,630 to 20,600 lb).
- Increased aft fuselage to increase fuel storage.

These changes were made to adapt the YF-17 to carrier operations, improve slow speed flight characteristics, and extend the internal fuel range. Though the F/A-18 is generally based on the YF-17 prototype, it is often perceived as a very different aircraft. Nonetheless, lessons learned from the YF-17 experience did benefit the F/A-18 program.

ORIGINAL PLAN

The basic requirement for the F/A-18 (VFAX) was approved in April 1974 and constitutes formal program initiation for the purposes of this study.[1] Responses to the RFP were received in June from six

[1] Because the F/A-18 is based on the YF-17, program initiation is often taken to be the start of the Air Force's Lightweight Fighter Program in September 1971. Based on the information we obtained, it seemed more reasonable to define program start as approval of the formal requirement (VFAX). There is a 31 month difference between the start of the LWF program and the approval of the VFAX requirement.

contractors. However, the Congressional direction to terminate VFAX and choose either the YF-16 or YF-17 delayed the start of actual work. The Navy reissued the RFP as a modification to the Air Force's LWF RFP in October 1974. In January 1975, before the Navy could complete evaluation of the two aircraft, the Air Force selected the YF-16. In May 1975, the Navy selected the YF-17 as the most appropriate aircraft to fulfill the VFAX dual role carrier based strike fighter requirements and awarded short term contracts to McDonnell Douglas and Northrop (the two contractors formed a team in October 1974 to respond to the RFP) for $4.4 million and a $2.2 million contract to General Electric for the engines. DSARC II was planned at this time for August 1975. It was determined that 11 aircraft months of testing the two YF-17 aircraft was enough to support a DSARC II decision and move directly into full scale development.

The DSARC II meeting took place in December 1975. The plan approved at this time represents the earliest available acquisition plan for the F/A-18 program. It envisioned an FSD contract award for the airframe in January 1976 (GE had received an FSD contract for the engines in November 1975), with a first flight of a test aircraft in July 1978. Eleven FSD test aircraft were planned. Initial operational testing (NPE/IOT&E I) was to be complete in November 1978 and initial production approval (DSARC III) was scheduled for March 1980. Though the date for first production delivery was not given at this time, pilot production of nine aircraft was planned for 1979. The major risks were thought to be cost, system reliability, and integrated avionics. Other technical risks, such as composites in the structure and the fly-by-wire flight control system. were not mentioned as key risks.

Three factors tend to stand out as affecting the length of the original plan. First, the program was highly concurrent, with the initial production decision scheduled three months before completion of the initial test program (NPE/IOT&E IV completion was planned for June 1980). The perception of low technical risk, perhaps in part based on experience with the YF-17, may have been a contributing factor here. Second, the program seems to have been planned in an environment of adequate funding, and adequate funding was provided at the outset. Last, the Congressional direction to choose one of the LWF prototypes may have contributed. Since preliminary design, development, and testing of the YF-17 provided a sound technical basis, the F/A-18 program was able to enter FSD directly, rather than go through a Phase I concept exploration or prototyping phase. These three factors all seem to have contributed to a shorter original plan than otherwise might have occurred.

EVENTS AND DEVIATIONS

Table F.1 shows selected schedule milestones for the F/A-18 program. The dates under the revised plan columns are when program schedule changes were documented. There were several modifications to the original plan, particularly toward the end of development. However, measured from VFAX approval to the first production delivery in May 1980 (this is the first of the FY79 pilot production aircraft) the total program length was 73 months with no slip in first delivery. Many of the other program milestones did in fact slip, though apparently there was no adverse effect on first delivery.

The DSARC II FSD decision in December 1975 appears to coincide with the first detailed schedule for the F/A-18 program and represents the baseline plan. The FSD contract was awarded in January 1976 to McDonnell Douglas and included design, development, and fabrication of 11 test aircraft. First flight of a test aircraft was planned for July 1978, 30 months after contract award. However, by early 1978 it became clear that this goal would not be reached. First flight was rescheduled for September 1978 (a slip of two months) because of technical difficulties and in accordance with contract definitization. A corresponding two month slip in NPE/IOT&E I (November 78 to January 79) also resulted. At the same time, FY79 budget decisions regarding the procurement schedule resulted in a six month slip in IOC (September 82 to March 83). Rollout of the first test aircraft occurred in September 1978, but first flight did not occur until November, an additional two month slip in the first flight milestone. Reasons include contractor performance problems (late delivery of items) and allowing a more thorough evaluation of the digital fly-by-wire flight control system. Again a corresponding two month slip in completion of NPE/IOT&E I resulted (January to March 79). Technology transfer problems (from Northrop to McDonnell Douglas) appear to have played a part in this. NPE/IOT&E I was completed in April 1979 after an additional one month delay because the testing required more time.

These slips in milestones are graphically illustrated in Fig. F.1. which shows the evolution of the F/A-18 program schedule over time. The original plan can be read off the horizontal axis, and each evolution of the plan is indicated by changes in the milestone lines. The vertical axis provides the date when the schedule changes were reflected in program documentation. All milestone intervals are measured in months from VFAX approval. The figure shows the corresponding movement in first flight and completion of NPE/IOT&E I. The slips in these milestones do not appear to have affected other milestones.

Table F.1

F/A-18 MILESTONE TABLE

Milestone	Original Plan[a] (Mar 76)	Revised Plan[b] (Mar 78)	Revised Plan[c] (Sep 78)	Revised Plan[d] (Jun 79)	Revised Plan[e] (Dec 79)	Revised Plan[f] (Mar 80)	Revised Plan[g] (Jun 80)	Revised Plan[h] (Sep 80)	Revised Plan[j] (Dec 80)	Revised Plan[k] (Mar 81)	Actual Date[m]
VFAX approved	Apr 74										Apr 74
Design contract award	May 75										May 75
FSD contract award (engine)	Nov 75										Nov 75
DSARC II	Dec 75										Dec 75
FSD contract award (airframe)	Jan 76										Jan 76
First flight	Jul 78	Sep 78	Nov 78								Nov 78
NPE/IOT&E I complete	Nov 78	Jan 79	Mar 79	Apr 79							Apr 79
DSARC IIIa (initial production)	Mar 80					Apr 80	N/A				N/A
1st production delivery							May 80				May 80
NPE/IOT&E IV complete	Jun 80						Oct 80		Feb 81		Feb 81
Dedicated IOT&E (fighter)	Oct 80							Dec 80	Feb 81		Feb 81
DSARC IIIb (fighter, full production)	Nov 80						N/A				N/A
DSARC III (fighter)	N/A						Sep 80	Nov 80	Feb 81	Mar 81	Jun 81
Dedicated IOT&E (attack)	Dec 81						Feb 82			Aug 82	Nov 82
DSARC IIIc (attack, full production)	Jan 82						N/A				N/A
DSARC III (attack)	N/A						Sep 81	Sep 82			Dec 82
IOC	Sep 82	Mar 83			Sep 82		Dec 82				Mar 83

[a]31 March 76 SAR; Rothman, TASC Program Database: Program start is designated as approval of the VFAX requirement. Congress terminated the VFAX concept in August 1974 and directed the Navy to select one of the Air Force's LWF prototypes.

[b]31 March 78 SAR: 1st flight rescheduled from July 78 to September 78 in accordance with contract definitization. NPE/IOT&E I completion rescheduled from November 78 to January 79 to accommodate funding profile established during contract definitization. Six month slip in IOC due to FY79 budget decisions on procurement schedule.

Table F.1—continued

[c]30 September 78 SAR: 1st flight date delayed two months to permit thorough evaluation of the digital fly-by-wire flight control system and 1st flight occurred on 18 November 78 because of a combination of technical difficulties and contractor performance. NPE/IOT&E I delayed by delay in 1st flight.

[d]30 June 79 SAR: Delay in completion of NPE/IOT&E I because of 1st flight delay and testing requiring more time.

[e]31 December 79 SAR: Congressional direction to purchase additional aircraft in FY80 permits moving IOC back to September 82.

[f]31 March 80 SAR: DSARC IIIa rescheduled.

[g]30 June 80 SAR: DSARC IIIa changed to OSD program review for DSARC principals. DSARC IIIb redesignated DSARC III (fighter) and rescheduled for September 80. DSARC IIIc redesignated DSARC III (attack) and rescheduled for September 81. Changes to the DSARC process based on OSD program guidance of 13 May 80 and Program Review of 18 April 80. NPE completion posponed until after DSARC III (fighter). IOT&E (attack) rescheduled for September 81–February 82 to accommodate delays in contractor and Navy DT&E. IOC change in accordance with Weapon System Planning Document dated 13 June 80.

[h]30 September 80 SAR: DSARC III (fighter) date was redirected to 6 November 80 and will become an OSD program review. DSARC III (attack) corrected to agree with OSD program review guidance cited in June 80 SAR.

[j]31 December 80 SAR: NPE and IOT&E (fighter) were combined for program efficiency. The loss of F-12 delayed completion until February 81. Decision Memorandum of 17 December 80 established February 81 for DSARC III (fighter).

[k]30 March 81 SAR: Delay in DSARC III (fighter) since limited program review was scheduled and held on 17 March 81. IOT&E (attack) completion has slipped until August 82 because of slip in flight test schedule.

[m]DMS, Inc., "The F-18 Hornet," Military Aircraft, March 1986; TASC, Independent Schedule Assessment Database Systems Narratives for Fighter Aircraft, 17 July 86, TR-5300-3-3.

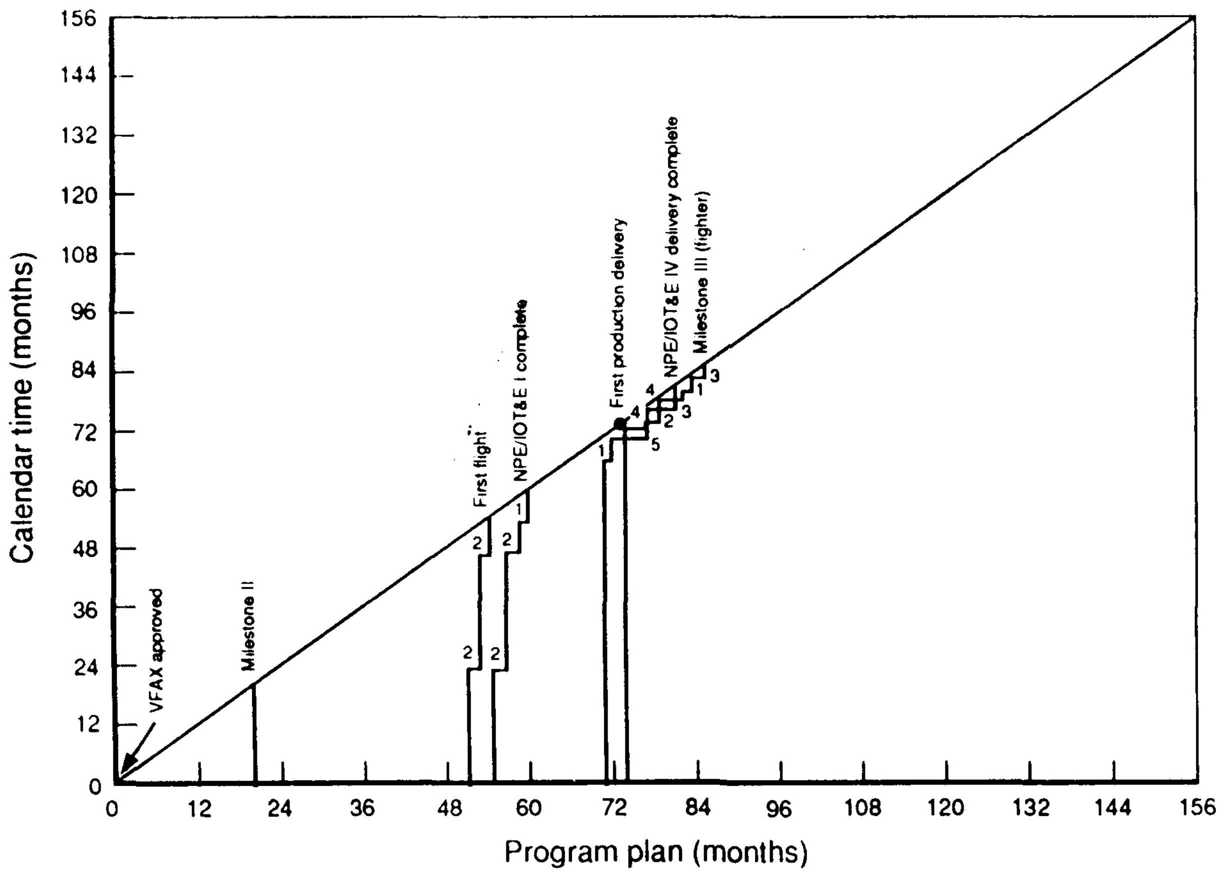

Fig F.1—F/A-18 schedule evolution

A DSARC program review in November 1978 approved release of FY79 funds for the nine aircraft pilot production lot. First delivery was scheduled for May 1980. Notice that this approval came before completion of NPE/IOT&E I and just after the first flight of the test aircraft, illustrating the highly concurrent program structure. The design-to-cost (DTC) goal, originally set at different levels for the attack and fighter versions, was at this time combined into one goal. It was decided that the two versions would be identical except for external stores, so only one design-to-cost (DTC) goal was necessary. This DTC decision begins to get at an interesting factor that affected some interim milestones, though not other technical milestones: concept stability. Apparently, there had been a debate within the Navy over whether the fighter or attack roles would be emphasized. It seemed mostly to affect the DSARC III production decision. The debate also tended to degrade the priority the Navy had for the F/A-18, resulting in an attempt at program cancellation two years after the FSD contract award.

Congressional direction to purchase additional aircraft in FY80 allowed IOC to be moved back up to the originally planned September 1982 date. First production delivery occurred as planned on May 1980. This was the first of the nine FY79 pilot production aircraft.

The DSARC III meeting originally planned for March 1980 was slipped one month (to April) and changed to a DSARC program review. Much of the remaining development testing and production decisions were then changed because of delays in flight test aircraft deliveries and problems discovered during testing. DSARC IIIa, initial production of the fighter version, was combined with DSARC IIIb (full production of the fighter) and rescheduled for September 1980. DSARC IIIc (full production, attack) was changed to DSARC III (attack) and rescheduled to September 1981, four months earlier than the previous DSARC IIIc. These changes to the DSARC process were based on the April 1980 DSARC program review and the resulting OSD guidance of May 1980. Completion of NPE/IOT&E IV was postponed until after the rescheduled DSARC III (fighter) milestone, and completion of dedicated IOT&E (attack) was delayed two months (December 81 to February 82) to accommodate delays in Navy and contractor DT&E. IOC was slipped three months (September 82 to December 82) in accordance with the Weapon System Planning Document dated June 13, 1980. This may have been influenced by a four to five month slip in the testing program to redesign the wing and correct a roll rate problem. These changes appear to be the only major program restructure in the F/A-18 program; they seem to be the result of Navy debates over fighter vs. attack emphasis (concept stability), technical problems in achieving DCP design goals, and late deliveries by the contractors resulting in extension of F/A-18 testing.

Sometime in late 1980, the DSARC III (fighter) decision was again changed to a program review and rescheduled for November 1980 (a two month delay). Completion of dedicated IOT&E (fighter) was slipped to December 1980 to correspond with this. Also, DSARC III (attack) was given as September 1982, apparently correcting an error in previous documents.

The November 1980 DSARC program review resulted in combining NPE/IOT&E IV and dedicated IOT&E (fighter) and rescheduling completion to February 1981. DSARC III (fighter) was again rescheduled to February 1981 (a three month delay). The loss of one flight test aircraft was cited as the reason for these changes.

DSARC III (fighter) again slipped by one month (February to March 81) and became a program review. Completion of dedicated IOT&E (attack) was slipped by six months (February to August 82) because of delays in the flight test program. DSARC III (fighter) actually occurred in June 1981 after an additional three month delay. The combined NPE/IOT&E IV and dedicated *IOT&E (fighter) was* completed on schedule in February 1981. IOC occurred in March 1983 after an additional three month delay (December 82 to March 83).

SUMMARY

Table F.2 summarizes the factors affecting the pace of the F/A-18 program. The total planned length of the program from program start (VFAX requirement approval) to first production delivery was 73 months. Measured in this way, the F/A-18 program experienced no slip in first delivery.

Several factors account for the length of the original plan. The plan was highly concurrent in development/production. In particular production decisions were scheduled before the completion of testing. This type of plan appears to have been accepted because technical risks were perceived as low, probably at least partly because of experience with the YF-17 prototype. The program also appears to have been planned in an environment of adequate funding, and initial funding likewise appears to have been adequate. External guidance in the form of Congressional direction to choose one of the LWF prototypes also seems to have played an important role in influencing the original plan. Choosing an aircraft with several years of prototype testing experience (at least the basic configuration of the F/A-18 if not the detail) may have allowed the Navy to avoid its own demonstration/

Table F.2

FACTORS AFFECTING PACE—F/A-18

	Original Plan	Deviation from Plan
Competition		
Concurrency	S	
Funding adequacy	S	
Prototype phase		
Separate contracting		
Service priority		
External guidance	S	
Joint management		
Program complexity		
Technical difficulty		
Concept stability		
Contractor performance		
External event		
Funding stability		
Major requirements stability		
Program manager turnover		
Total accounted for		
Unknown		
Total slip to first delivery		0

validation or prototyping phase and jump right to FSD. These three factors all seem to have contributed to making the original plan shorter than it otherwise might have been. Unfortunately, available information does not allow a more detailed breakdown of the relative contribution of each factor to the length of the original plan.

Although there was no slip in first production delivery, many of the interim milestones did slip. In particular, technical difficulties, late deliveries by contractors, and problems discovered during testing all seem to have affected these interim milestones from before the first flight of the test aircraft. These slips did not affect first production delivery. For instance, while the planned DSARC III production decision was changed several times, the DSARC program reviews still gave approval to release of funds for pilot and initial production. It was the full rate production decision that was continually delayed, having its greatest affect on IOC rather than first delivery.

A contributing factor in the slips of the F/A-18 interim milestones was the debate between attack and fighter organizations within the Navy. This form of concept instability must have contributed to some confusion on the part of program managers and contractors as to exactly what end item was desired. It is unknown how much this factor actually contributed to slips in interim milestones.

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Appendix G

JOINT TACTICAL INFORMATION DISTRIBUTION SYSTEM (JTIDS)

This appendix briefly summarizes the factors affecting the pace of the Joint Tactical Information Distribution System (JTIDS), a secure, jam resistant tactical communication system for both data and voice. The JTIDS program is highly complex, in terms of both management and technology. There are three basic type of terminals: Class 1 for Navy ships and submarines and both Navy and Air Force airborne early warning radar systems (E-2C, E-3A); Class 2 for smaller weapon system platforms, including fighter and attack aircraft; and Class 3 to meet Army man-portable and vehicle requirements. Additionally, there are two different but related technologies: Time Division Multiple Access (TDMA) and Distributed TDMA (DTDMA). The focus here is on the Air Force/Army Class 2 TDMA terminal portion of the program, though some discussion of the Navy DTDMA program is also included. Class 1 terminals reached production before FSD start for Class 2 terminals, and Class 3 has not yet reached advanced development.

The information contained here comes from various sources, including public literature, program documentation, and interviews with program office personnel. The bibliography provides several references describing the various technologies in more detail than will be done here.

BACKGROUND

The JTIDS program is an outgrowth of the Air Force SEEK BUS program and the Navy Integrated Tactical Air Control System (ITACS) and Integrated Tactical Navigation System (ITNS) programs, all three in advanced development during the early 1970s. The SEEK BUS program was in turn based on two previous Air Force programs that proved the feasibility and utility of the JTIDS concept: the Position Location Reporting and Control of Tactical Aircraft, and Integrated Communication, Navigation, and Identification System programs. These efforts were similar to the Navy's ITACS and ITNS programs: All involved developing TDMA technology.

JTIDS addressed a need throughout all three services for a secure, jam resistant, tactical communication (data and voice) system for use on command and control platforms (Class 1 terminals), fighters and attack aircraft, and ground air defense units (Class 2). When JTIDS was established, there was no system that met these needs. In addition, JTIDS was to provide position and navigation data (through inherent system capabilities: timing of message arrival) and an inherent identification capability. The basic difference between the TDMA and DTDMA technology concerns the time sequencing of messages. TDMA requires that all terminals be in sync at the outset of a mission with only minor adjustment flexibility, while DTDMA allowed greater flexibility to adjust message timing during a mission. Additionally, DTDMA emphasized voice and data, while TDMA was primarily for data with a secondary voice capability. The Air Force and the Army operational concepts—air defense management—could be met with TDMA, whereas JTIDS was to be the primary tactical communications system for the Navy and Marine Corps, requiring the use of DTDMA technology. DTDMA included a TDMA mode for interoperability. The technical challenge of DTDMA was greater than TDMA, and size constraints were also tighter: TDMA Class 2 terminals could be 1.6 cubic feet and weigh 125 lb, while DTDMA Class 2 terminals needed to be 1.3 cubic feet because of F/A-18 space constraints. Each terminal includes an antenna set, a receiver/transmitter group, signal processor, and digital display (for platforms without this capability).

The Air Force is the lead agency for JTIDS TDMA and manages the program in a joint program office (JPO) in the Electronic Systems Division of the Air Force Systems Command. The Air Force provides the program manager and a deputy program manager (DPM), and the Army, Navy, and Marine Corps each have a DPM. Program funding is provided by each service through its DPM. Additionally, there is close coordination between the JPO and the E-3A, TRI-TAC, GPS, PLRS, F-14, F-15, F-16, F/A-18, DAIS, BASIC, and the JCS JINTACCS programs. The Joint Logistics Command (JLC) was to have oversight and review roles and provided the top level decision authority for resolution of interservice issues. The Navy manages the Navy/Marine Corp DTDMA program within the Space and Naval Warfare Systems Command. Users include Air Force and Army air defense units, Navy battle groups, and Marine divisions.

ORIGINAL PLAN

There was little documentation available on the JTIDS Class 2 TDMA original plan. A September 1974 DDR&E decision to consolidate the SEEK BUS, ITACS, and ITNS programs into the JTIDS program constitutes program initiation. The joint management charter for the newly established JTIDS JPO was approved January 1975. Several versions of program management directives (PMDs) and program management plans (PMPs) were issued during Phase I, with PMDs published in June 1976, June 1977, January 1979, and October 1979, and a PMP in June 1979. The schedule milestones listed in these documents changed with each revision, however; these schedules apparently were not officially approved through the DSARC and DCP process.[1] Hence, no program baseline was established until FSD start in January 1981. The January 1979 PMD listed Class 2 terminal schedule milestones as follows:

ATDMA FSD contract award	August 1979
F-15 Component contract	September 1979
F-16 Component contract	October 1981
DT&E/IOT&E	May 1981–June 1982
Production decision	September 1982
Start production	October 1982
Initial production delivery	March 1984

ATDMA (Advanced Time Division Multiple Access) was to be an advanced version of the basic TDMA terminal. This schedule is adopted here as the original plan, though it seems likely that earlier schedules existed. Program schedule slips will most likely be underestimated if there were earlier plans.

JTIDS was to be developed as an incremental, evolutionary system. Class I terminals were developed first and entered low rate production in July 1980, with first delivery in June 1982. Class 2 TDMA terminals (the subject of this appendix) were in advanced development (Phase I) while Class I terminals were in FSD. The original plan (January 79 PMD) scheduled FSD contract award (and by inference Milestone II) for August 1979, 59 months after program start. Since DT&E start usually corresponds to first FSD delivery, first Class 2 FSD terminal delivery was planned for May 1981, 21 months after contract award. Testing was to be completed in June 1982, 13 months later. The production decision was planned for September 1982, 37 months after FSD start, with first production delivery 18 months later in March 1984. The total planned program length was 114 months from the September 1974 OSD direction constituting program initiation to first production delivery. Phase I was planned to be 59 months and Phase II 55 months. Notice that Phase I was planned to be several months longer than Phase II, a somewhat uncommon occurrence that cannot be adequately explained at this time.

[1]General Accounting Office, *The Joint Tactical Information Distribution System—How Important Is It?* PSAD-80-22, January 30, 1980.

Five factors appear to account for the length of the original plan. The September 1974 OSD direction to consolidate the Air Force SEEK BUS and Navy ITACS and ITNS programs appears to be a major factor. The resulting joint program management structure, necessitating interservice coordination, complicates program planning and budgeting, especially given the different operational concepts of the services. Additionally, there were separate contracts planned for Phase I, Phase II, and production. Program complexity also affected the plan. JTIDS was to be integrated into many different platforms, including Navy ships and submarines, ASW platforms, Navy and Air Force airborne early warning systems (E-2C, E-3A), tactical fighter and attack aircraft, and Army air defense systems. NATO interoperability was also a concern. These factors tended to lengthen the original plan. However, each service claimed that JTIDS was high priority, as it provided an urgent capability (secure, jam resistant communication) not currently satisfied by any other deployed or planned system. High service priority tends to shorten program schedules.

EVENTS AND DEVIATIONS

Table G.1 shows selected milestones for the JTIDS Class 2 TDMA program. The dates under the revised plan columns give the date at which program schedule changes were documented and formally incorporated into a revised schedule. The milestone labeled "program initiation" refers to the approval of the joint operational requirement document and does not constitute program start by the definitions used here. As stated previously, formal program initiation is defined as the September 1974 OSD direction to consolidate existing Air Force and Navy programs under a single JPO.

According to Table G.1, the original plan, measured from the September 1974 OSD direction to first operational delivery, was 114 months, 59 months in Phase I and 55 months in Phase II. The actual program length (estimate as of December 1987) is 204 months, which included a 17 month slip in Phase I and a 73 month slip in Phase II. Data were not available to adequately trace schedule evolution during Phase I, though some data from various sources were available and are discussed below.

Phase I Events

The joint operational requirement for JTIDS was released March 1976. JTIDS was designated a major program in November 1977. An

Table G.1

JTIDS TDMA MILESTONE TABLE

Milestone	Original Plan[a] (Jan 79)	Revised Plan[b] (Jan 81)	Revised Plan[c] (Jun 82)	Revised Plan[d] (Jun 83)	Revised Plan[e] (Sep 83)	Revised Plan[f] (Dec 83)	Revised Plan[g] (Dec 84)	Revised Plan[h] (Dec 85)	Revised Plan[j] (Sep 86)	Revised Plan[k] (Dec 86)	Actual Date[m] (Dec 87)
Program initiation (JOR)		Mar 76									Mar 76
Class 2 ADM delivery		Aug 78									Aug 78
Milestone II		Jan 81									Jan 81
FSD contract award	Aug 79	Jan 81									Jan 81
Pod preliminary OT&E		Jan 82									Jan 82
1st Class 2 FSD delivery (Army)		Apr 83	May 83	Aug 83	Dec 83	Apr 84	Mar 84				Mar 84
1st Class 2 FSD delivery (AF)		Jul 83	Aug 83	Nov 83	Jan 84	May 84	Jun 84				Jun 84
1st Class 2 FSD delivery (Navy)		n/a								Jul 89	Sep 89
Army unique DT/OT		Dec 84		Jun 85	Sep 85	Feb 86	Jul 86			Apr 87	Apr 87
AF testing complete	Jun 82	Jan 86	Mar 85	Jun 85	Sep 85	Mar 86	Nov 86	Mar 87		Apr 87	Apr 87
Milestone III (Army/AF)	Sep 82	Jun 86	Jun 85	Sep 85	Dec 85	May 86	Jan 87	Mar 87	Jun 87		May 89
Production contract award		Jun 86	Jun 85	Sep 85	Dec 85	May 86	Mar 87		Jun 87		May 89
Milestone IIIa (Navy)		n/a								Dec 91	Dec 91
Begin Navy TECHEVAL		n/a								Dec 91	Aug 92
Begin Navy OPEVAL		n/a								May 92	Feb 93
Milestone IIIb (Navy)		n/a								Dec 92	Sep 93
PLRS/JTIDS hybrid ASARC		Oct 86				Dec 85	Feb 85	n/a			n/a
Army FUE		Nov 86				Jul 88			Aug 89	n/a	n/a
1st production delivery (Army/AF)	Mar 84	Jun 88	Jun 87			May 88	Mar 89		Jun 89		Sep 91
1st production delivery (Navy)		n/a								Dec 93	Dec 93
IOC (AF)	Aug 84	Sep 88	Dec 88			Dec 89			Dec 89		Mar 92
IOC (Army)		Oct 89				Oct 88			Jan 90		Sep 92
IOC (Navy)		n/a								Dec 93	Dec 93

[a]PMD No. R-S 4057(6)/64754/JTIDS, 29 January 1979: This is the 3rd PMD and replaces a June 77 PMD. It is the earliest schedule available, though it is not comprehensive. Milestone names listed in the PMD differ from those in the SAR: Functionally similar milestones were matched.

[b]AF SAR, 30 June 82: Data are from Development Estimate, which reflects baseline established at January 81 DSARC IIa and documented in January 81 SDDM and March 81 DCP.

Table G.1—continued

[c]AF SAR, 30 June 82: (These changes all occurred before June 82 SAR reporting period.) FSD terminal deliveries have been adjusted one month to accomplish design work associated with PACKED four message structure and February 82 TADIL J message implementation. AF test program was reduced from a full production modification in the F-15 and F-16 DT&E/IOT&E to a test-only modification to the F-15 only with a shortened test program (F-15 IOT&E only). DSARC III production decision changed from June 86 to June 85 to correspond with end of F-15 testing. Production contract and 1st delivery changed due to change in DSARC III. IOC reflects change in definition from initial deliveries to operational squadron (F-15) with full JTIDS capability.

[d]AF SAR, 30 June 83: No changes noted in September 82 and December 82 SARs. Changes reflect publication by JCS (JINTACCS) of Tactical Data Information Link (TADIL) J catalog in January 83. The change impacts technical baseline. Incorporation of change into terminal design impacted software development test schedules, production decision and production contract award.

[e]AF SAR, 30 September 83: Changes to FSD terminal delivery, test, and production milestones due to incorporation of TADIL J message standard into design, and delays in completing initial terminal integration and testing.

[f]AF SAR, 31 December 83: FSD terminal deliveries adjusted to permit incorporation of July 82 TADIL J and to ensure interoperability and completion of hardware/software integration and test. Test program adjustments made to accommodate terminal delivery change. Production decision and contract award were adjusted to permit reporting of test results. Army PJH, FUE and IOC adjusted to reflect schedule in Army PJH SAR of June 83. 1st production delivery will occur 24 months after contract award. AF IOC adjusted to reflect delay in initial terminal delivery.

[g]AF SAR, 31 December 84: The first Army FSD terminal was delivered four days early. The first AF FSD terminal was delivered one month late because of hardware/software integration problems. The start of Army unique DT/OT slipped five months because of hardware/software integration problems. The completion of AF testing has been delayed eight months: six months because of hardware/software integration and two months because of test asset availability and schedule adjustments mandated by new test time frame. Milestone III adjusted eight months due to delay in completion of AF testing. The production contract award was delayed ten months: eight months due to delay in testing and two months due to new DT&E review cycle. The ASARC for the PJH slipped two months. 1st production delivery slipped due to slip in contract award.

[h]AF SAR, 31 December 85: The end of AF testing slipped two months due to delay in the arrival of F-15s to Eglin AFB. Milestone III slipped two months due to delay in AF DT&E. The SECARMY decided that PJH could continue into FSD without an ASARC.

[j]AF SAR, 30 September 86: The Class 2 DT&E/IOT&E slipped two months, which caused a three month delay in JRMB III, production contract award, and 1st delivery. Army PJH program delays caused slips in Army FUE and IOC; these are Army PJH program slips only with no effect on JTIDS.

[k]AF SAR, 31 December 86: This is the first consolidated tri-service SAR. The end of Army testing slipped nine months (July 86 to April 87) and AF testing slipped one month (March to April 87) because DT&E was extended. No impact on other milestones.

[m]AF SAR, 31 December 87: (All dates prior to December 87 are actuals: all others are most currest estimates.) Navy milestone changes due to major program restructure from FY88 Congressional reductions in Navy RDT&E. The first Navy FSD terminal delivery was delayed due to Navy decision to to delay procurement until reliability is improved. Army decision to procure only Class 2M terminals results in slip for Army milestones. The production decision (AF) slipped from June 87 to May 89 due to a Congressional requirement that the terminal demonstrate 400 hour MTBF (lab) prior to production decision. This change delayed subsequent milestones.

April 1978 DSARC program review apparently provided general program guidance, but no DCP with a baseline schedule. Milestones appear to have been revised several times during Phase I, but there is no actual documentation to support this. There was a DSARC IIa scheduled for August 1979 (January 79 PMD), apparently changed successively to September 1979, February 1980, and June 1980 by various OSD memoranda. The planned DSARC IIb (to decide the technology issue; choose between basic TDMA, ATDMA, and DTDMA) date of December 1980 was similarly changed to March 1981. The advanced development contract appears to have included fabrication of five advanced development models (prototypes), the first of which was delivered in August 1978. Other than the January 1979 data discussed previously, there are no data available on other program milestones established during Phase I.

Milestone II and FSD contract award actually occurred in January 1981, 17 months later than planned. Phase I actual length was 76 months, a slip of 29 percent from the original plan. Reasons for this slip include concept stability (neither the operational concept nor the technology were stable during this period) and funding *stability* (in August 1979, the Air Force deleted JTIDS funding from its FY81 budget due to cost growth and technical difficulties during Phase I: OSD later restored most the funding). However, the scant available documentation was insufficient to identify the factors affecting the Phase I deviation.

Phase II Events

Figure G.1 shows the JTIDS program schedule evolution based on the FSD baseline schedule. The horizontal axis gives the planned schedule and the vertical axis gives the date when program changes were documented. All data are in months from program start (September 1974). The numbers on the figure give the months of slip associated with each event. For the first delivery milestone, the factors affecting the deviations are listed on the right, with the numbers corresponding to months of slip associated with each factor. In the case of JTIDS, changes in milestones are reflected almost identically in downstream milestones.

DSARC IIa occurred on January 1981 and an FSD contract was awarded to Singer-Kearfott Division for 20 FSD units (five Army, 15 Air Force). Rockwell-Collins was also awarded a follower contract as part of the leader/follower acquisition strategy. The preliminary design review was completed in October 1981, and the critical design review was begun in December 1981 and completed in July 1982. The DSARC IIb meeting included in some early JTIDS related documents

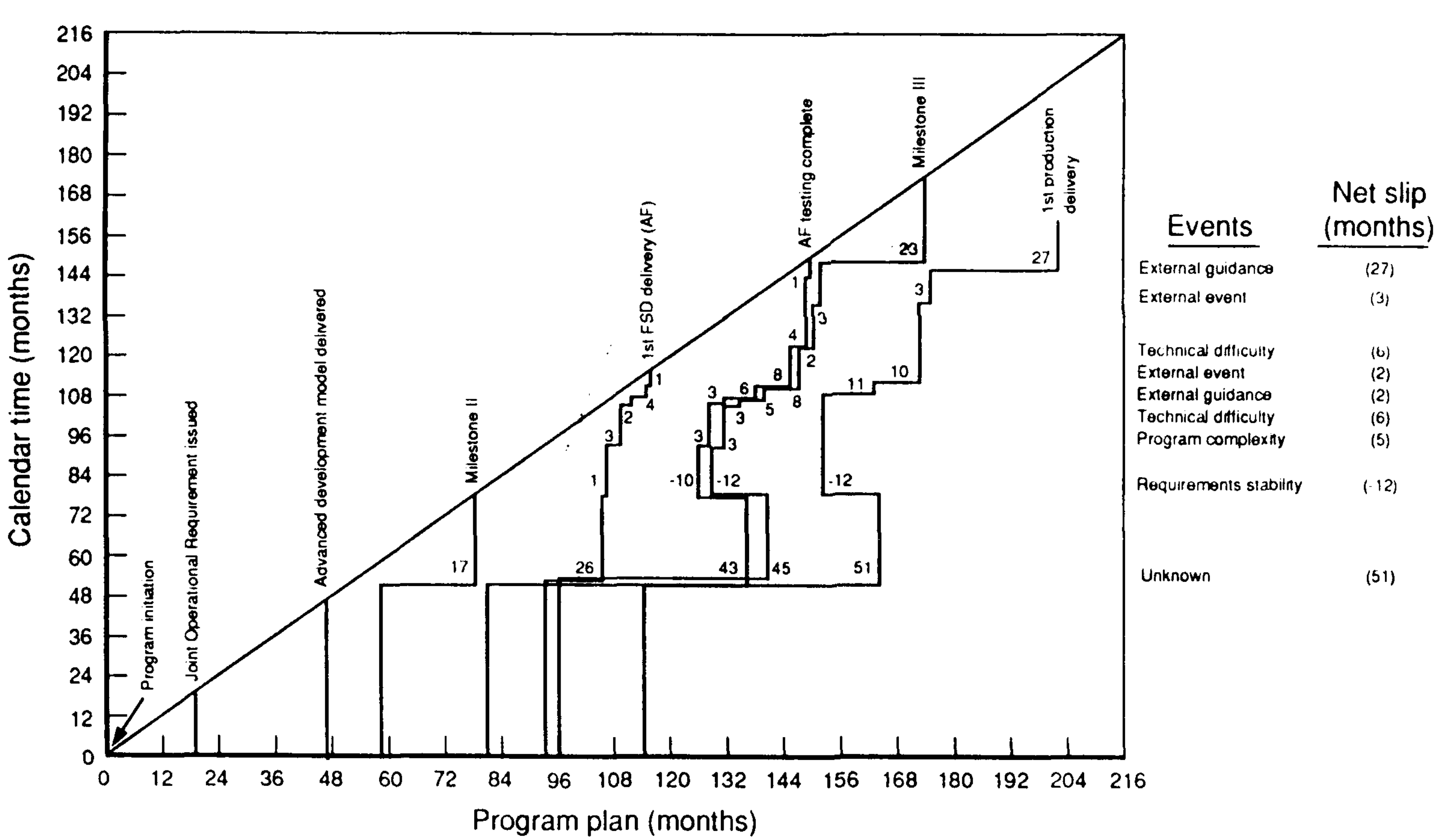

Fig. G.1—JTIDS TDMA schedule evolution

was not included as part of the baseline schedule established at FSD start and documented in the initial *Selected Acquisition Report* for JTIDS (December 81).

The Class 2 baseline established at FSD start (DSARC II in January 1981 and documented in the initial DCP dated March 1981) was the first comprehensive program schedule. The first Army FSD terminal was to be delivered in April 1983 and the first Air Force FSD terminal in July 1983 (26 months later than originally planned). The Navy was not part of TDMA development program at this time. Army unique DT/OT would be completed in December 1984, and Air Force DT&E/IOT&E would be completed in January 1986 (43 months later than planned). The Milestone III production decision and contract award were planned for June 1986 (45 month slip) with first production delivery 24 months later in June 1988 (51 month slip). Air Force IOC was planned for September 1988. Army IOC was planned for October 1989; however, this date was a function of the Army Position Location and Reporting System/JTIDS Hybrid program (PJH—Army deployment concept) and not a function of the JTIDS program. At Milestone II, the Air Force JTIDS Class 2 TDMA FSD program was planned to be 89 months long, from FSD contract award to first production delivery. The factors that caused the considerable slip in program milestones from the original plan to the FSD baseline (51 month slip in first production delivery) cannot be accounted for in available program documentation. Possible reasons include a better understanding of the technical challenges or program complexity involved.

Before June 1982, several events caused program schedule adjustments. Most of the adjustments accelerated the program. FSD terminal deliveries for both the Army and the Air Force were delayed one month (April to May 83 and July to August 83 respectively) to accomplish design work associated with the PACKED 4 message structure and the TADIL J (Tactical Data Information Link for JTIDS) issued in February 1982. A reduction in the Air Force planned test program, from a full modification of F-15 and F-16 aircraft to support DT&E/IOT&E to a limited F-15 modification only shortened the test program by ten months (January 86 to March 85). This implies that the required demonstrated performance for a production decision was reduced. The production decision milestone and production contract award were changed accordingly by 12 months (from June 86 to June 85), as was first delivery, which remained scheduled for 24 months after production contract award. The three month slip in IOC date actually reflects a change of definition, from initial deliveries to full operational capability in an F-15 squadron.

By June 1983, the delivery, testing, and production milestones were again adjusted. The January 1983 TADIL J publication by the JCS JINTACCS affected the technical baseline of JTIDS. Design changes were necessary to incorporate the new message standard. Hardware design changes in turn affected software development. The result was a three month slip in first FSD terminal delivery for both the Army and Air Force, a three month delay in completion of both Army and Air Force testing, and a three month delay in Milestone III and the production contract. No changes in first production delivery were documented at this time.

The same set of milestones were again delayed by September 1983 and for the same reason: TADIL J message structure forced design changes in JTIDS hardware and software. FSD first deliveries slipped four months for the Army and two months for the Air Force. Testing and production decision milestones all slipped another three months. By December 1983, these same milestones were again adjusted for the same reason. The revised plan was more comprehensive, however. FSD deliveries were delayed four months, Army testing five months, Air Force testing six months, and production decision and contract award milestones five months. First production delivery was adjusted based on the accumulated slips since June 1982 to May 1988 (11 months). Air Force IOC was delayed until December 1989 and Army IOC until October 1988 (based on the PJH schedule). Hardware/software integration problems affecting the FSD terminal deliveries were the apparent driver here.

The December 1984 revised plan showed first FSD terminal delivery to the Army in March 1984, one month early (actually four days early, but one month by our accounting technique). Air Force FSD terminal delivery occurred in June 1984, one month later than the most recent plan because of hardware/software integration difficulties. Both were delivered 11 months later than planned at FSD start. Continued integration problems resulted in an additional five month slip in Army DT/OT completion and six month slip in Air Force DT&E/IOT&E completion. Air Force testing slipped an additional two months because of test asset availability. Milestone III was delayed eight months to account for the delay in Air Force testing. The production contract award was delayed eight months because of the testing delay, and two months for a new DT&E review cycle. First production delivery slipped ten months but remained 24 months after contract award.

By December 1985, Air Force testing had slipped by another two months because of a delay in the arrival of F-15s to Eglin AFB. This affected the production contract award. Of particular note during this time period was the cancellation of the Navy's DTDMA program directed in an October 1985 letter from the Secretary of the Navy. The Navy was directed to join the Air Force and Army program, though Navy milestones did not show up in the joint *Selected Acquisition Report* until December 1986. Neither the Navy DTDMA program nor the Navy TDMA milestones are discussed here, though the existence of this program, administered by SPAWARs and not the JTIDS JPO, did affect the JTIDS TDMA program, felt mostly in interservice competition and the annual demands from Congress to pick one technology and develop it exclusively. The House Armed Services Committee finally withheld future funding for either program until one technology was chosen. Cost growth, technical difficulties, and contractor performance caused substantial delays in the Navy's DTDMA program, resulting in eventual termination. Table G.2 shows selected milestones for the Navy DTDMA program.

The other milestone delays shown in Table G.1 and Fig. G.1 were caused by factors previously discussed. Two exceptions are worthy of

Table G.2

JTIDS DTDMA MILESTONE TABLE

Milestone	Original Plan[a] (Jul 84)	Revised Plan[b] (Sep 84)	Revised Plan[c] (Feb 85)	Revised Plan[d] (Dec 85)	Revised Plan[e] (Apr 87)	Actual Date
DSARC IIb		Jan 82				Jan 82
1st Class 2 FSD delivery		Jun 85	Dec 85	Aug 88	Jul 89	
OT IIa	Oct 86	Oct 86	Jul 87	Jun 89	Jun 90	
OT IIb				Oct 89	Aug 91	
DSARC IIIa		Mar 87	Nov 87	Oct 89	Oct 90	
Begin LRIP	Jun 87	Jun 87	Feb 88	Oct 89	Oct 90	
Start TECHEVAL	Aug 87	Aug 87	Mar 88	Jan 91	Aug 91	
Complete TECHEVAL	Dec 87	Dec 87	Sep 88	Mar 91	Dec 91	
Start OPEVAL	Mar 88	Mar 88	Dec 88	May 91	Feb 92	
Complete OPEVAL	Sep 88	Sep 88	Jun 89	Aug 91	May 92	
DSARC IIIb		Dec 88	Sep 89	Feb 90	Dec 91	
DNSARC IIIc				Feb 91	Feb 92	
IOC	Dec 88	Dec 88	Sep 89	Dec 91	Sep 92	
Full rate production		Feb 89	Oct 89	Jan 92	Oct 92	

[a]Navy JTIDS, Transition from Development to Production, briefing, July 84.
[b]Navy JTIDS, Program Status for DSARC Principals, 26 September 84.
[c]Navy JTIDS, Secretary of the Navy Program Review, 28 March 85.
[d]Navy JTIDS, Navy Program Schedule, 19 December 85.
[e]Navy JTIDS, POM-90 Program Schedule, 13 April 87. This schedule corresponds to the Navy switch to TDMA technology.

note. Air Force and Army testing continued to slip because of technical problems, affecting other milestones. The April 1987 test completion date appears to be an administrative milestone only: The test program was extended (and was continuing as of December 87) to correct deficiencies discovered during the earlier test program. However, the names of the tests were changed, resulting in the appearance of completion. Of particular interest are the reliability failures of the system during testing. In response to this problem, Congress directed that JTIDS demonstrate a 400 hour MTBF performance (in the lab) prior to production decision and contract award. The December 1987 schedule shows the result: a 23 month (June 87 to May 89) delay in production contract award and a 27 month delay (June 89 to September 91) in first production delivery.

SUMMARY

Table G.3 summarizes the factors affecting the pace of the Air Force JTIDS Class 2 TDMA program. The September 1974 OSD direction to combine the Air Force SEEK BUS and Navy ITACS and ITNS programs appears to be a major factor affecting the length of the plan. Interservice coordination complicates program planning and budgeting, especially given the different operational concepts of the services. Additionally, there were separate contracts for Phase I, Phase II, and production. Program complexity also affected the plan: JTIDS was to be integrated into many different platforms, including Navy ships and submarines, ASW platforms, Navy and Air Force airborne early warning systems (E-2C, E-3A), tactical fighter and attack aircraft, and Army air defense systems. NATO interoperability was also a concern. These factors tended to lengthen the original plan. However, each service claimed that JTIDS was high priority, as it provided an urgent capability (secure, jam resistant communication) not currently fulfilled by any other deployed or planned system. High service priority tends to shorten program schedules.

The factors causing the 51 month slip in first production delivery incurred during Phase I are unknown. Five factors account for the 39 months of the Phase II schedule slip in the Air Force/Army JTIDS program. Major requirements stability caused a 12 month acceleration (June 88 to June 87) because of a reduction in testing program requirements. The required level of performance demonstrated before a production decision was apparently reduced. There is an implied funding constraint as well. Technical difficulty in the form of hardware/software integration problems led to two different six month delays: a

Table G.3

FACTORS AFFECTING PACE—JTIDS TDMA

	Original Plan	Deviation from Plan
Competition		
Concurrency		
Funding adequacy		
Prototype phase		
Separate contracting	L	
Service priority	S	
External guidance	L	29 (Congressional restriction, DT&E review cycle)
Joint management	L	
Program complexity	L	5 (TADIL J)
Technical difficulty		12 (integration)
Concept stability		
Contractor performance		
External event		5 (test asset availability)
Funding stability		
Major requirements stability		−12 (reduction in test reqts)
Program manager turnover		
Total accounted for		39
Unknown		51
Total slip to first delivery		90

portion of the 11 month slip from June 87 to May 88 and a portion of the ten month slip from May 88 to March 89. Program complexity—incorporation of the TADIL J message standard written by JCS JINTACCS office—caused redesign and appears to have accounted for about five months of the 11 month slip from June 87 to May 88. Two external events related to the test program caused five months of schedule slip: two month slip due to test asset availability (portion of July 87 to May 88 slip), and three month slip due to delay in F-15 test aircraft arrival at Eglin AFB (March to June 89). Last, external guidance caused a two month slip (portion of June 87 to May 88 slip) because of revised DT&E review cycle and 27 month slip because of Congressional direction to demonstrate 400 hour MTBF reliability (June 89 to September 91).

The JTIDS Class 2 TDMA program incurred a net total of 90 months of slip from program start to first delivery. Most of this (51 months, 57 percent) was delays: incurred during Phase I. The remaining 39 months of slip (43 percent) was incurred during Phase II and is fully accounted for by the five factors discussed above.

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Appendix H

LANTIRN PROGRAM

This appendix briefly summarizes the factors affecting the pace of the Low Altitude Navigation and Targeting Infrared System for Night (LANTIRN) program, a dual pod system that improves the ability of single-seat aircraft to perform low altitude ground attack missions at night in all weather. The information comes from various sources, including public literature, program documentation, and interviews with program office personnel.

BACKGROUND

The LANTIRN program addressed a perception of an urgent need by the Tactical Air Command (TAC)—improving low altitude navigation and targeting capabilities of single-seat (and therefore single pilot) aircraft in all weather and at night. LANTIRN was to provide both the A-10 and F-16 with "high accuracy capabilities to acquire, track, and destroy ground targets with single-seat aircraft."[1] Pave Spike and Pave Tack had provided TAC with similar equipment and capability since about 1973, but LANTIRN would be a substantial improvement over these past systems.

LANTIRN is managed in a system program office in the Aeronautical Systems Division of the Air Force Systems Command. TAC is the using organization. The basic requirement was to improve ground attack capabilities of single seat aircraft in all weather and at night. In particular, the automatic target recognition (ATR) requirement represented the core of the LANTIRN concept, allowing single pass detection and weapon delivery. Minimizing the effects on airframes, wiring, and cockpit configurations were important design constraints.

LANTIRN consists of three parts: a navigation pod that includes a forward looking infrared (FLIR) and terrain-following radar; a targeting pod that includes a FLIR, a weapon handoff coordinator (in particular for the IR Maverick missile), and an automatic target recognizer (in the original concept); and a head-up display (HUD). The HUD would be installed in the aircraft cockpit, and the pods could be used

[1]Acquisition Plan, Number 80-1A-63249F, March 1980.

separately or together. The two pods together are referred to as the fire control system (FCS).

ORIGINAL PLAN

LANTIRN began in late 1979 with a small team developing the acquisition strategy and schedules. Formal program initiation was in December 1979. The original plan, signed off in March 1980 and coincidental with the planned FCS contract award, outlined a 51 month schedule from contract award to first operational delivery of the FCS. The was no demonstration/validation phase in LANTIRN. In fact, though LANTIRN meets the criteria for a major weapon system in the OSD review process, a waiver was requested and approved based on the tight schedule. LANTIRN is not a DSARC program and therefore has no formal Milestone reviews. The original plan envisioned a two phase FSD program lasting 37 months and beginning at contract award. The contract also specified production options, making the original acquisition strategy appear similar to a total package procurement.

Phase I, to last 18 months, was to be a competitive parallel development effort with two contractors for the FCS, though only one for the HUD. Phase I of FCS development included design, development, and fabrication of the FCS through a Critical Design Review. This was to be followed by a technical demonstration and competitive hardware testing through the end of the phase. A down-select to one FCS contractor would then occur.

Phase II of FSD, with a single contractor for the FCS, would include delivery of six FSD prototypes and comprehensive testing on both the F-16 and A-10. This phase was to last 19 months. A production readiness contract was to be awarded concurrently with the start of Phase II, with the first delivery of a production prototype at the end of the phase. The production options in the contract included two lots, the first for 51 pods and the second for 144 pods.

The HUD portion of the program was scheduled to coincide with the FCS milestones. The FSD phase was also to last 37 months, and included delivery of ten HUDs (six F-16, four A-10). Two production lot options were also included, for 110 and 150 units respectively.

The original plan also included a brief assessment of program risk. For the FCS portion, technical risk was rated as moderate to high in both FSD and production, the former because of the incorporation of new technology (the ATR) and packaging and weight requirements, the latter because of the concurrency between FSD and production and the rapid buildup to full rate production. Schedule risk was rated as high in both FSD and production because the aggressive plan meant that technical problems would affect the schedule. The schedule was considered optimistic, with little or no flexibility to allow for program changes. Cost risk was rated as moderate to high in both FSD and production for reasons related to the technical and schedule risks. The contract was to be a fixed cost fixed fee type. The HUD portion of the program in both FSD and production was similarly rated as moderate to high risk in terms of technical, schedule, and cost goals.

The perception of an urgent requirement, implying a high service priority, seems to have driven the aggressive schedule in the original plan. The lack of separate contracting between program phases and the inclusion of substantial concurrency also contributed to the short schedule. In addition, the original Program Management Directive (PMD) was the basis for the original plan. The schedule in the PMD was based on an earlier plan that included a very short, highly ambitious schedule. Unfortunately, it is not possible to determine the relative effect of each of these on the formation of the original plan. Technical difficulty apparently was not considered in the original plan, except to recognize that technical risks were fairly high and caused cost and schedule risks to be high.

EVENTS AND DEVIATIONS

Table H.1 shows the milestones for the LANTIRN program. The dates under the revised plan columns are when program changes were identified in program documentation. As one can see, there were several major schedule changes throughout the life of the program. Measuring from program initiation to the first production delivery of the target pod, the total actual program length was 103 months, or 1.8 times as long as originally planned.

Changes to the original plan took place even before the contract was awarded.[2] Further cost analyses revealed cost and affordability constraints that resulted in substantial changes to the original acquisition strategy. This seems to have been complicated by an internal Air Force debate regarding system concept definition. The FSD phase for the FCS was changed to a single phase, single contractor approach, though the time from contract award to first production delivery remained 51 months, and the FSD portion remained 37 months.[3] It appears that there was some change in strategy but no change in

[2]The HUD contract appears to have been awarded on schedule in July 1980 to Marconi Avionics Ltd. (U.K.). The following discussion focuses on the FCS.

[3]Acquisition Plan, Number 80-1A-63249F, Amendment 01, September 1980.

Table H.1

LANTIRN MILESTONE TABLE

Milestone	Original Plan[a] (Mar 80)	Revised Plan[b] (Sep 80)	Revised Plan[c] (Dec 82)	Revised Plan[d] (Dec 83)	Revised Plan[e] (Dec 85)	Actual Date[f] (Dec 86)
Program initiation	Dec 79					Dec 79
Contract award (HUD)	Jul 80					Jul 80
Contract award (FCS)	Mar 80	Sep 80				Sep 80
HUD F-16 flight test complete	Jun 82	Jul 82	Dec 82			Dec 82
HUD A-10 flight test complete	Nov 82	Nov 82	Dec 82			Dec 82
HUD F-16 production decision	Jul 82	Feb 83	Jan 83	Feb 85	Dec 84	Dec 84
HUD A-10 production decision	Jul 83	Dec 83	May 83	Jul 88	N/A	N/A
1st FSD navigation pod delivery	Jul 82	Nov 82	Feb 83	Feb 83	Feb 83	Feb 83
1st FSD targeting pod delivery	Jul 82	Nov 82	Jul 83	Jul 83	Jul 83	Jul 83
ATR advance development technical evaluation	N/A	N/A	Oct 84	Oct 84	Oct 84	Oct 84
Competitive target pod flyoff	N/A	N/A	Dec 84	N/A	N/A	N/A
FCS F-16 flight test complete	Jun 83	Oct 83	Dec 84	Dec 84	Sep 85(Nav) Mar 86 (Tar)	Sep 85 Mar 86
FCS production decision (long lead)	Jan 82	Feb 83	Feb 85	Feb 85(Nav) Feb 86(Tar)	Mar 85(Nav) May 86(Tar)	Mar 85 May 86

Table H.1—continued

Milestone	Original Plan[a] (Mar 80)	Revised Plan[b] (Sep 80)	Revised Plan[c] (Dec 82)	Revised Plan[d] (Dec 83)	Revised Plan[e] (Dec 85)	Actual Date[f] (Dec 86)
FCS production start	Jun 83	Dec 83	Nov 85	Feb 85	—	
FCS F-15E flight test complete	N/A	N/A		May 88	Aug 88	Aug 88
FCS A-10 flight test complete	Jun 83	Oct 83	Sep 87	Nov 90	N/A	N/A
1st FCS production delivery	Aug 84	Dec 84	Aug 87	TBD	Apr 87(Nav) TBD(Tar)	Apr 87 Jul 88
IOC	—	—	TBD	TBD	FY89(Nav) TBD(Tar)	FY89 FY90

NOTE: This is not a DSARC program: no DCPs or SDDMs.

[a]Acquisition Plan, March 80.

[b]Acquisition Plan, Amendment 01, September 80: Acquisition strategy change due to further cost analysis resulting in affordability questions. FSD now single phase with one contractor, but total time to first production delivery remains 51 months.

[c]31 December 82 SAR (DE line): This was the first SAR. Before this (September 81) there was a major program restructure to reduce risk: ATR held in competitive advanced development. A January 83 decision to equip only 250 F-16s delayed LANTIRN HUD production decision until February 85.

[d]31 December 83 SAR (CE line): HUD A-10 production decision changed to more accurately reflect aircraft need date. FCS A-10 flight test completion delayed because of funding cuts. No funds were provided in FY83-84 DoD Appropriation Acts for targeting pod competitive flyoff. F-15E FCS flight test completion date from 31 December 85 SAR (AP line). First delivery dates to be determined based on negotiated agreement.

[e]31 December 85 SAR (CE line): A-10 aircraft requirement deleted. Previous dates were July 88 and December 89 for A-10 HUD production decision and FCS flight test completion respectively. Additional time required for completion of F-16 FCS flight test. Production decision on targeting pod delayed to complete IOT&E. Previous date was February 86. August 84 program restructure to match President's Budget for FY85-87 and incorporate F-15E. This delayed target pod by one year.

[f]31 December 86 SAR (CE line): First delivery dates for pods reflect contract.

contract milestones. The competitive 18 month Phase I FSD plan was dropped, though the single contractor selected was required to design and develop two different ATR systems using different technical approaches. The single 37 month FSD phase included six FSD prototypes, one set of support equipment, and a similar amount of testing. The contract type was changed to fixed cost incentive fee, though the ATR portion was cost plus fixed fee. The production readiness option was still planned to be exercised in the 19 month from contract award. The production lot options now included three lots of 34, 138, and 128. The strategy change does not seem to have reduced concurrency between development and production, and other than contract type, the contracting strategy still resembled a total package procurement. Additionally, the risk ratings and the reasons for the ratings did not change with the change in strategy. The strategy change took four months to implement, and this was reflected in all downstream FCS milestones .

The FCS contract was awarded to Martin Marietta in September 1980 after a brief paper competition with Ford Aerospace. Ford immediately filed a protest with the GAO and a suit with the District Court. Both involved RFP specifications and interpretations. In December 1980, the court ruled in favor of Martin Marietta. Though this does not appear to have affected the schedule, it did tie up SPO personnel.

Schedule changes after the contract award are shown in Fig. H.1. The horizontal axis shows the original plan and its evolution as reflected in particular milestones. The vertical axis provides the date when the program change was reflected in program documentation.

After the four month slip in the contract award, the next major program change came in 1981. It appears that the program encountered problems immediately after contract award, including funding adequacy and cost growth problems, as well as technical difficulties. In September 1981 the program was restructured to reduce program risks. This included holding the ATR in advanced development until the technology was more mature and delaying both the production decision (24 months from February 83 to February 85) and the first production delivery (32 months from December 84 to August 87). The deliveries of the FSD navigation and target pods were also delayed (three and eight months respectively). Concurrency was reduced when the production options were removed from the initial contract. The overriding concern here appears to have been technical difficulties, though future funding adequacy and stability concerns also played an important role. Both FSD pods were delivered on schedule under the revised plan, with the first navigation pod delivery in February 1983 and the first target pod in July 1983.

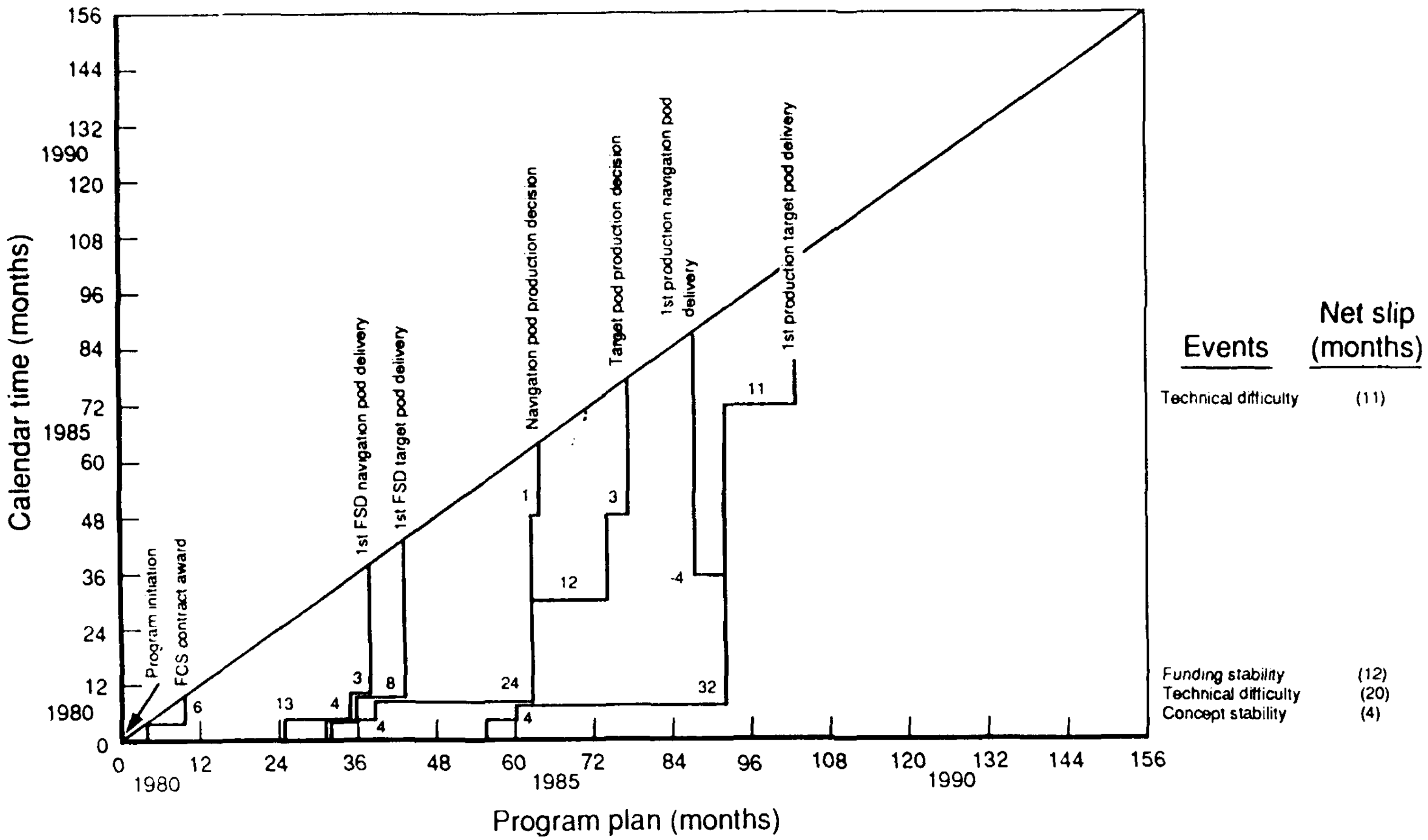

Fig. H.1—LANTIRN schedule evolution

There was considerable Congressional action on LANTIRN during both the FY 1982 and 1983 authorization and appropriation process. The essence of the Congressional concern stemmed from the perception of rather large cost growth experienced by the program, a perceived duplication of effort with respect to the FLIR in the targeting pod, and contractor technical difficulties. In both the fiscal year authorization acts, Congress directed the LANTIRN SPO to conduct a competitive flyoff between the LANTIRN targeting pod and the F/A-18 FLIR system. The Air Force agreed to this and the SPO began planning, but funding was never forthcoming. Although this process took the time and effort of SPO personnel, it does not appear to have affected other schedule milestones. The competitive testing would have been incorporated into the existing targeting pod test program and would not have affected the planned production decision.

In August 1984 the program was again restructured. As part of a series of budget cuts to bring the program in line with the President's Budget for FY85–87, OSD deferred the targeting pod production decision one year (from February 85 to February 86), though the navigation pod production decision remained as scheduled (February 85). The targeting pod was again experiencing technical difficulties that delayed testing. At the same time, the F-15E was added as a platform for the LANTIRN. During the previous year, the number of LANTIRN sets required for the F-16 was reduced from 1380 (all F-16C/Ds) to 250. By December 1985, the requirement for the A-10 was dropped because of funding constraints.

A contract was awarded to Martin Marietta in February 1985 for navigation pod production, with first delivery in April 1987. This schedule was maintained. The targeting pod, however, remained about one year behind. Low rate production was approved in June 1986 with a scheduled first delivery in June 1988. Contract negotiations resulted in a planned July 1988 first delivery for the targeting pod.

SUMMARY

Table H.2 presents a summary of the factors affecting the pace of the LANTIRN program. Most of these have been previously discussed, but a brief recap is in order, as the LANTIRN program is considerably more complex than it first appears. The total planned length of the program was 56 months (including the time between program initiation and contract award) while the total actual program length was 103 months to first production delivery, a slip of 47 months or about 84 percent of the original plan.

Table H.2

FACTORS AFFECTING PACE—LANTIRN

	Original Plan	Deviation from Plan
Competition		
Concurrency	S	
Funding adequacy		
Prototype phase		
Separate contracting	S	
Service priority	S	
External guidance	S	
Joint management		
Program complexity		
Technical difficulty		20 (September 81 restructure: ATR, reduce risk) 11 (target pod)
Concept stability		4 (system concept definition)
Contractor performance		
External event		
Funding stability		12 (September 81 restructure)
Major requirements stability		
Program manager turnover		
Total accounted for		47
Unknown		0
Total slip to first delivery		47

In terms of factors affecting the original plan, four stand out. First is service priority. The capability represented by LANTIRN appears to have been an urgent requirement on TAC's part, thus pushing for a short, aggressive schedule. The high degree of concurrency between development and production, particularly in terms of a production readiness decision halfway through FSD, seems to have contributed to a short schedule, as did the lack of separate contracting. Additionally, the schedule in the original PMD was based on an earlier plan that included a very short, highly ambitious schedule. This is an example of external guidance. Though we can not determine the relative importance of each of these factors, technical difficulty seems not to have been a determinant, even though LANTIRN incorporated new technology and represented a rather high technical risk. The major program restructure in September 1981 changed the acquisition strategy with respect to the factors mentioned: It reduced concurrency and incorporated separate contracting and, by removing the ATR requirement, considerably reduced the technical difficulty of the program.

In terms of deviations from the plan, the delay between the planned and actual contract award dates appears to be due to the realization (after further cost analysis) that parallel development efforts was not affordable. The major program restructure in September 1981 appears to be due to technical difficulty (particularly in the targeting pod), complicated by funding concerns; it accounts for the largest share of the slip. Similar technical problems appear to have further delayed both the production decision and delivery dates of the targeting pod, while the navigation pod (and the HUD) remained on schedule after the major program restructure.

LANTIRN, acknowledged as a difficult program incorporating advanced technology, did not have a demonstration/validation phase. Because of the complexity of the program, a pre-FSD hardware demonstration to better understand the technical challenges involved might have contributed to a smoother FSD program.

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Appendix I

M1 ABRAMS

This appendix briefly summarizes the factors affecting the pace of the M1 Abrams program, the Army's new main battle tank powered by a 1500 hp turbine engine and mounting a 105mm gun.[1] The information presented here comes from various sources, including public literature, program documentation, and interviews with project office personnel.

BACKGROUND

The M1 program results from over a decade of work by the Army to develop a new main battle tank to replace the M60 series. As early as 1961, studies were begun in cooperation with West Germany on requirements and designs for a new tank. In 1963, the MBT-70 program was initiated, a collaborative effort with West Germany and one of the first attempts at weapon system co-development with a NATO country. However, because of the difficulty associated with developing design requirements for the MBT-70 that would meet both U.S. and FRG needs, technical problems, cost growth, and schedule slip associated with the program, the MBT-70 effort was canceled in January 1970 after producing only six prototypes (the first appeared in 1967). The U.S. Army then began development of an austere version of the MBT-70, the XM-803, while the FRG initiated the Leopard II program. Again cost growth and technical problems caused Congress to cancel the XM-803 program in December 1971. At the same time, Congress directed that the Army initiate a new tank program using a competitive prototype approach and provided $20 million in RDT&E funding for this effort.

Based on this direction, the Vice Chief of Staff of the Army directed in January 1972 that a Materiel Need (MN) document be developed covering the need for, the requirements of, and various program alternatives for a new main battle tank program. To carry out this directive, the Main Battle Tank Task Force (MBTTF) was formed with

[1]The original M1 is armed with a 105mm gun, while the M1A1, a follow-on product improvement of the M1, is armed with a 120mm gun. This appendix describes the original M1 configuration.

participants from the user, trainer, and developer organizations with a report to be issued by August 1972. In March 1972, the Chief of Staff of the Army directed that the new tank be fielded (contract award to IOC) in six years, one to four years faster than previous U.S. and foreign experience with tank development. This acceleration directive was a response to concerns that the acquisition cycle was taking too long to develop new weapon systems. At about the same time, the Deputy Secretary of Defense recommended that new programs use a "fly-before-buy" approach, including both advanced development and production prototypes.

The MBTTF report was issued in August 1972. Along with a statement of need and alternative design configurations, the report also provided several acquisition strategy options for the various program phases. For the development phases, these included:

- A single contractor in validation and FSD.
- Two validation phase contractors with a down-select to a single contractor for FSD.
- Two contractors in both validation and FSD.

An October 1972 ASARC I eliminated the first option because of Congressional interest in competitive prototyping, and eliminated the third option because of excessive cost. The ASARC recommended the second option, with sole source production and low rate initial production approval at a DSARC IIa and first production delivery in just over six years. DSARC I met in November 1972 marking the formal start of the XM-1 program.[2]

Management of the M1 program began in a program office within the Army's Tank and Automotive Command, a division of the Army Materiel Command. As the program evolved, and other tank programs (e.g., M60A4) were begun, the program office was renamed Tank Systems, with the M1 Abrams tank managed in a project office within the Tank Systems Program Office.

The M1 was developed as a replacement for the M60 series of tanks. It provides improvements over the M60 in survivability, mobility, shoot-on-the-move, hit probability, and night fighting. The M1 was also designed for increased reliability, availability, maintainability, and durability (RAM-D). It is powered by the AVCO Lycoming AGT-1500, a 1500 hp regenerative turbine engine. The M1 is the first land vehicle to use a turbine engine. The main armament is a 105mm gun, and the

[2]The M1 program was initiated as the XM-815, and later as the XM-1. These names are used interchangeably here and all relate to a new main battle tank with a 105mm gun.

M1 also mounts three machine guns. Other M1 equipment includes a laser rangefinder, a solid state digital computer, stabilized day/night thermal sights, and a turret stabilization system. The M1 is operated by a crew of four.

ORIGINAL PLAN

DSARC I took place in November 1972, marking formal program initiation. However, because of controversies regarding a design-to-cost goal and the weight of the proposed tank, no decision was reached at this time. The DSARC met again in December and approved the program as recommended by the ASARC. This included a competitive prototyping phase with two contractors, followed by FSD with a single contractor, and sole source production beginning with low rate initial production to be approved at a DSARC IIa/III. The time from validation contract award to first delivery would be just over six years, with approval for full rate production in seven years. In January 1973, the Secretary of Defense approved the plan and signed DCP No. 117, which also specified a design-to-cost goal of $507,790 (FY72$) and the use of proven hardware. The RFP released in January to Ford, Chrysler, and General Motors also prioritized 16 performance categories. No detailed performance specifications were given, allowing the contractors flexibility to make performance tradeoffs to attain the DTC goal.

Proposals from Chrysler and General Motors were submitted in May 1973; Ford had declined to bid. In June, validation phase contracts were awarded to Chrysler and GM for $68.1 million and $87 million respectively. Each contractor was required to fabricate one prototype, one ballistic, and one automotive test rig as part of the validation phase effort. The prototypes were to be delivered in February 1976, at which time a combined DT/OT I would begin. DT/OT I was to be complete in May 1976, with DSARC II scheduled for June. The contractor selected at the end of the validation phase would receive an FSD contract in July 1976, with DT/OT II to begin in November 1977/February 1978 and end in February 1979. At this time, DSARC IIa/III and the low rate initial production (LRIP) contract award were not scheduled: These milestones would be scheduled when there was adequate DT/OT II information available to support an LRIP decision. DT/OT III was to start in November 1979/February 1980 and the full rate production decision (DSARC IIIa) and contract award in August 1980. Based on the DT/OT III start date, first production delivery can be assumed to have been planned for October 1979, 83 months after DSARC I.

Five factors appear to account for the length of the original plan. Perhaps most important are two forms of external guidance. When Congress canceled the XM-803 program, it also provided $20 million to initiate a new tank program and directed that a competitive prototyping strategy be used. About the same time, the Deputy Secretary of Defense initiated a "fly-before-buy" prototyping policy for weapon system development. Because of these directives, the Army incorporated both a competitive validation phase and prototyping into the original plan. These factors are generally believed to lengthen a program, though no definitive evidence supports this notion. Perhaps more important was the direction by the Chief of Staff of the Army to field a new tank in six years. Accomplishing this meant accelerating the acquisition process, achievable by incorporating concurrency between development and production. The combined developmental and operational testing plans and the overlap between LRIP and DT/OT III are measures of concurrency in the M1 program. Finally, the M1 was one of the Army's "Big 5" programs and had a high service priority. That, coupled with Congressional concern regarding the length of the acquisition cycle and the Army's two unsuccessful attempts to develop a new tank (the MBT-70 and XM-803), may have provided extra motivation to accelerate the program. For the M1, schedule received as much attention as cost and performance.

EVENTS AND DEVIATIONS

Table I.1 shows selected schedule milestones for the M1 program. The dates under the revised plan columns are when a program change was reflected in program documentation. The original plan, measured from DSARC I to first delivery, was 83 months. The actual program length was 87 months, a four month slip in first delivery. Many of the interim milestones also deviated from the original plan.

Phase I

Phase I of the M1 program appears to have run fairly smoothly. From contract award in June 1973 to the completion of DT/OT I in May 1976 (a period of 35 months) there were apparently no major program changes. In December 1974, the DSARC II date was slipped by one month (from June 76 to July 76), but this was basically an administrative change and did not reflect development problems. In the same month, the United States and FRG signed a Memorandum of Understanding to standardize their new tanks to the extent possible,

Table I.1

M1 MILESTONE TABLE

Milestone	Original Plan[a] (Sep 73)	Revised Plan[b] (Dec 74)	Revised Plan[c] (Sep 76)	Revised Plan[d] (Dec 76)	Revised Plan[e] (Mar 77)	Revised Plan[f] (Dec 77)	Revised Plan[g] (Sep 78)	Revised Plan[h] (Dec 78)
DSARC I	Nov 72							
Validation contract award	Jun 73							
DT/OT I								
Start	Feb 76							
Complete	May 76							
DSARC II	Jun 76	Jul 76		Nov 76				
FSD contract award	Jul 76		Nov 76					
DT/OT II								
Start	Nov 77/Feb 78		Mar 78/Aug 78	Mar 78/May 78	Feb 78/Apr 78	Feb 78/May 78		
Complete	Feb 79		Jun 79	Jul 79/Dec 79				Jul 79/Feb 79
DSARC IIa/III				Feb 79/Mar 79			Apr 79	
Low rate initial production contract award				May 79				
First production delivery	Oct 79		Feb 80					
DT/OT III								
Start	Nov 79/Feb 80		Mar 80/Jun 80	Mar 80/May 80	Mar 80/Jun 80			
Complete	Oct 80		Feb 80	Nov 80	Dec 80			
IOC								
DSARC IIIa	Aug 80		Dec 80	Feb 81				
Full production contract	Aug 80		Dec 80	Feb 81				

[a] 30 September 73 SAR: DSARC IIa/III will be scheduled and LRIP contract award will be made when there is adequate DT/OT II information available to support a LRIP decision. First production delivery assumed based on DT/OT III start date.

[b] 31 December 74 SAR: Administrative change to DSARC II.

[c] 30 September 76 SAR. Milestone changes all reflect 21 July 76 SECDEF decision to incorporate selected standardized (with FRG Leopard II) components in XM-1 design.

[d] 31 December 76 SAR: DSARC II and FSD contract award adjusted to reflect delay due to SECDEF decision; DSARC IIa/III and LRIP contract award added based on FSD schedule; OT II and OT III start dates adjusted to include initiation of crew training.

[e] 31 March 77 SAR: FSD contract award in early November vs. late November allowed a one month acceleration in DT/OT II start; OT III start date adjusted to allow shipment of vehicle produced in May 80; OT III completion adjusted to include completion of report.

[f] 31 December 77 SAR: OT II start date adjusted to reflect actual start of vehicle testing.

[g] 30 September 78 SAR: DSARC IIa/III LRIP decision adjusted to facilitate analysis of DT/OT II data.

[h] 31 December 78 SAR: OT II completion changed from December 78 to February 79 due to hardware problems affecting the availability of vehicles and a three week standown in August to fix these problems.

Table I.1—continued

Milestone	Plan[j] (Mar 79)	Plan[k] (Jun 79)	Plan[m] (Sep 79)	Plan[n] (Mar 80)	Plan[p] (Dec 80)	Plan[q] (Mar 81)	Plan[r] (Sep 81)	Plan[s] (Dec 86)
DSARC I								Nov 72
Validation contract award								Jun 73
DT/OT I								
Start								Feb 76
Complete								May 76
DSARC II								Nov 76
FSD contract award								Nov 76
DT/OT II								
Start								Feb 78/May 78
Complete								Sep 79/Feb 79
DSARC IIa/III	Nov 79/Feb 79	Sep 79/Feb 79						Apr 79
Low rate initial production contract award								May 79
First production delivery				Feb 80				Feb 80
DT/OT III								
Start				Mar 80/Sep 80				Mar 80/Sep 80
Complete			Jun 81/Apr 81	Sep 81/May 81			Nov 81/May 81	Nov 81/May 81
IOC			CY 80		Jan 81			Jan 81
DSARC IIIa			Jun 81		Oct 81	Sep 81		Sep 81
Full production contract			Aug 81		Oct 81	Sep 81	Oct 81	Oct 81

[j]31 Mar 79 SAR: DT II completion date changed to prove out RAM-D characteristics (technical problems).

[k]30 June 79 SAR: DT II completion date updated to reflect current estimate.

[m]30 September 79 SAR: DT/OT III completion dates changed to reflect current estimates; DSARC IIIa delayed four months to ensure completion and report preparation of all reliability testing from DT/OT III; delay in full production contract award corresponds to delay in DSARC IIIa.

[n]31 March 80 SAR: DT/OT III start and completion dates changed due to expansion of prototype vehicle test by contractor from two to six months, redistribution of test assets, and delays in production delivery schedule.

[p]31 December 80 SAR: Requirement for remedial gunnery training and Christmas holiday caused two week slip in IOC; DSARC IIIa based on changes to milestone review date; full production contract reflects reservation of option to procure an additional 209 XM-1s in FY81.

[q]31 March 81 SAR: Milestone review date changed to permit option execution; production contract change same as previous SAR.

[r]30 September 81 SAR: One month delay in DT III completion due to additional test requirements and lack of replacement spare parts, delay in completion of contract negotiations caused one month delay in award of production contract.

[s]31 December 86 SAR: Actual dates of accomplishment.

but no formal changes in either the M1 or Leopard II programs occurred at that time. The M1 prototypes were delivered on schedule in February 1976, when DT/OT I commenced. Both prototypes used a 105mm gun as the main armament. The major difference between the prototypes was the engines: GM used an improved version of an existing diesel engine (Teledyne Continental Motors AVCR 1360) and Chrysler used a turbine engine (AVCO Lycoming AGT 1500), the first time turbine engine technology was applied to tanks. DT/OT I was completed on schedule in May 1976, with contract award planned for July.

The first major slip occurred in July 1976 and affected the remaining program schedule. ASARC II had occurred in June 1976, and there is some indication that GM had been selected to enter into FSD.[3] However, the Secretary of Defense delayed contract award four months (to November 1976) allowing both contractors to incorporate certain standardized equipment in the design. The two contractors resubmitted their FSD proposals in November. GM's proposal increased slightly to reflect the needed design changes, while Chrysler's proposal decreased by about $30 million. Chrysler was chosen to proceed into FSD in November. As a result of the four month delay, Phase II milestones were changed considerably. DT/OT II would start in March/August 1978 and be completed in June 1979, a four month slip. The approval for LRIP (DSARC IIa/III) and the LRIP contract award, not previously scheduled, were planned for February/March 1979 and May 1979 respectively. First production delivery can be assumed to have slipped to February 1980 (four months). DSARC IIIa (full rate production approval) and the full rate production contract award were scheduled for February 1981, a slip of six months in each of these milestones. (These two milestones had been scheduled to occur in December 1980, a slip of four months from the original plan, after the SECDEF decision but before contract award.) This was the baseline schedule going into FSD.

Phase II

Figure I.1 illustrates the evolution of the M1 program schedule. The original plan is read off the horizontal axis, and subsequent changes in the schedule are reflected by changes in the lines denoting selected milestones. The vertical axis provides the date when schedule changes were reflected in program documentation. The numbers indicate the

[3] Richard Mendel, "The First Chrysler Bail-out: The M-1 Tank," *Washington Monthly*, February 1987, p. 17.

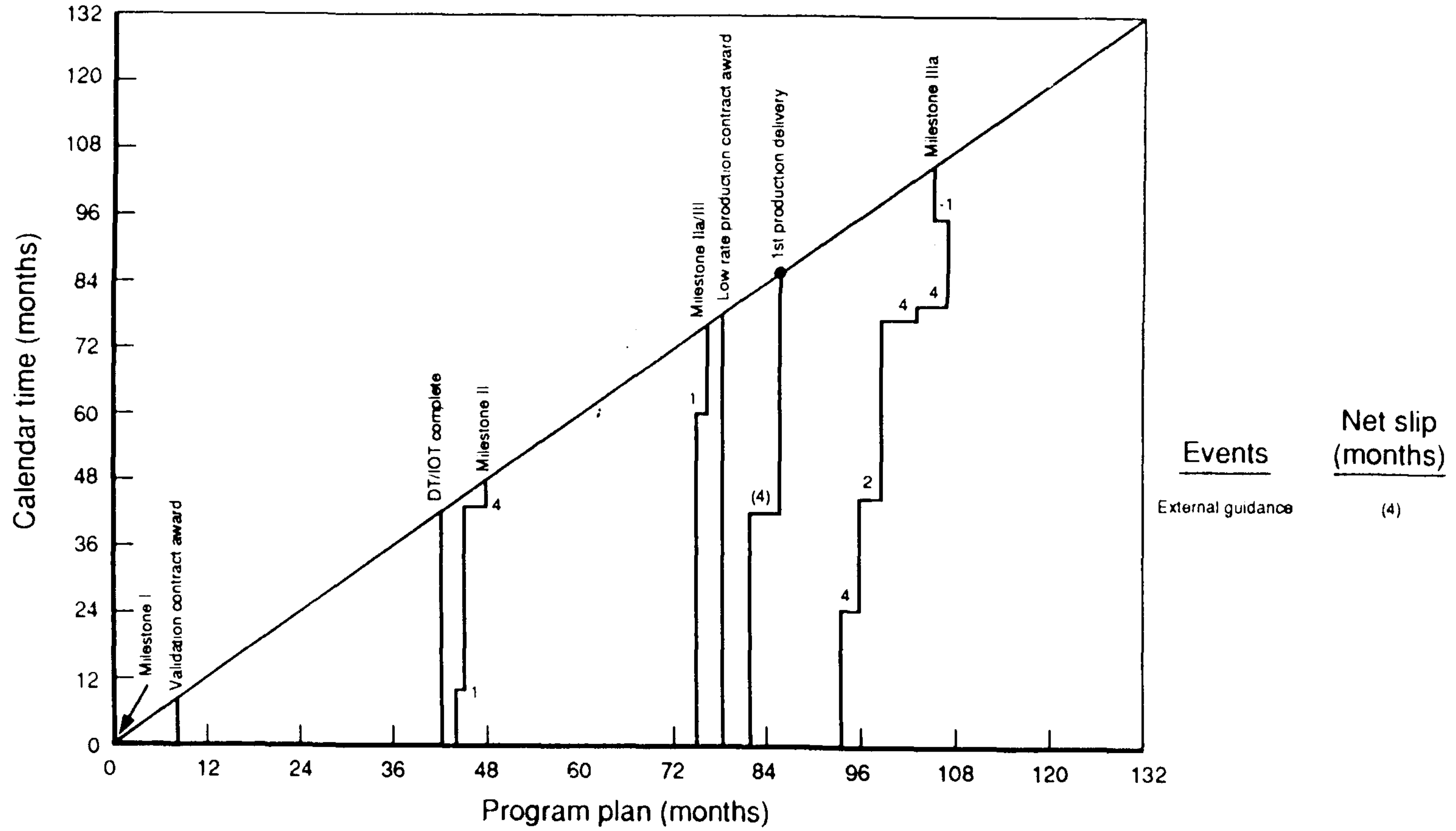

Fig. I.1—M1 schedule evolution

months of slip in each milestone associated with particular events. For the M1, contract awards for the various phases generally paralleled the decision milestones shown on the figure and usually occurred in the same month.

Chrysler received a $196.4 million FSD contract in November 1976. It included fabrication of 11 pilot vehicles to support DT/OT II. In January 1977 the Secretary of the Army announced that the 120mm gun used on the West German Leopard II would be incorporated onto the M1 in future production lots. This was the M1E1 (later the M1A1) and it would also include other preplanned product improvements. Meanwhile, work on the original M1 with a 105mm gun proceeded. The first pilot vehicles were delivered in February 1978 and DT II commenced. OT II began in May 1978. In late 1978, DSARC IIa/III was delayed one month (from March 79 to April 79) to facilitate analysis of DT/OT II results, and completion of OT II was slipped two months as a result of hardware problems. These technical difficulties mostly concerned the power train (engine, transmission, and final drive). The engine caused the most problems: Apparently, applying a turbine engine to a tank was somewhat more complicated than expected. Engine RAM-D characteristics were not met during OT II. DT II completion was slipped to November 1978 as a result of these problems.

Nonetheless, DSARC IIa/III occurred in April 1979 and the LRIP contract was awarded to Chrysler in May. Production start-up problems and a FY80 budget cut of $100 million caused a restructuring of the production program. In late 1979, the DT/OT III completion dates were changed to reflect current estimates given the RAM-D problems (from December 80 to June/April 81), and DSARC IIIa was delayed four months to ensure completion of DT/OT III and report preparation of all reliability testing. DT/OT III used LRIP vehicles in the testing. The full rate production contract was delayed six months to August 1981 as a result of the other milestone delays. The first LRIP vehicles were delivered as planned in February 1980, and in March DT III began. At the same time, OT III start was delayed three months to September 1980 and DT/OT III completion was scheduled for September/May 1981, a slip of three months and one month respectively. These testing schedule changes occurred because of delays in production deliveries (rate), expansion of contractor testing from two to six months, and a redistribution of test assets.

IOC occurred in January 1981 with LRIP vehicles before completion of DT/OT III. Testing was completed in November/May 1981, and DSARC IIIa occurred in September 1981. The full rate production contract was awarded in October 1981.

SUMMARY

Table I.2 summarizes the factors affecting the pace of the M1 program. The total planned length of the program from DSARC I to first production delivery appears to have been 87 months, with no apparent slip in first delivery.

Five factors appear to account for the length of the original plan. Perhaps most important are two somewhat conflicting forms of external guidance. When Congress canceled the XM-803 program, $20 million was provided to initiate a new tank program using a competitive prototyping strategy. About the same time, the Deputy Secretary of Defense initiated a "fly-before-buy" prototyping policy for weapon system development. Because of these directives, the Army incorporated both a competitive validation phase and prototyping into the original plan. These factors are generally believed to lengthen a program, though no definitive evidence exists to support this notion. Perhaps more important, and contributing to shortening the plan, was the direction by the Chief of Staff of the Army to field a new tank in six years. Accomplishing this meant accelerating the acquisition process by incorporating concurrency between development and production,

Table I.2

FACTORS AFFECTING PACE—M1

	Original Plan	Deviation from Plan
Competition	L	
Concurrency	S	
Funding adequacy		
Prototype phase	L	
Separate contracting		
Service priority	S	
External guidance	S	4 (SECDEF decision delay)
Joint management		
Program complexity		
Technical difficulty		
Concept stability		
Contractor performance		
External event		
Funding stability		
Major requirements stability		
Program manager turnover		
Total accounted for		4
Unknown		0
Total slip to first delivery		4

particularly in testing. The M1 program had highly concurrent development and operational testing in all phases of the program. While this does accelerate a program, it also tends to exaggerate problems as the same technical problems occur in both development and operational testing, which in turn exacerbates the concern of agencies outside the actual development process (e.g., Congress, OSD). Finally, the M1 was one of the Army's "Big 5" programs, and had a high service priority, which, coupled with Congressional concern regarding the length of the acquisition cycle and the Army's two unsuccessful attempts to develop a new tank (the MBT-70 and XM-803), may have provided extra motivation to accelerate the program.

External guidance from the SECDEF delayed the program by four months at the end of Phase I, the biggest program restructure for the M1 and resulting in the four month slip in first delivery. Although the LRIP contract was awarded as planned (again, this milestone was not documented in the original plan), approval for full rate production was delayed by 13 months, mostly as a result of technical problems in the M1's power train relating the RAM-D characteristics.

The accelerated strategy used did *in fact result in fielding* a new tank in slightly less time than the average of previous efforts: IOC occurred about eight years after program initiation.

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Appendix J

MULTIPLE LAUNCH ROCKET SYSTEM (MLRS)

This appendix briefly summarizes the factors affecting the pace of the Multiple Launch Rocket System (MLRS), a mobile rocket artillery system designed to supplement cannon artillery weapons. MLRS consists of two basic subsystems; the self-propelled launcher loader (SPLL), a derivative of the Bradley Infantry Fighting Vehicle chassis, and the rockets that act as the delivery vehicle for various submunitions. The information contained here comes from various sources, including public literature, program documentation, and interviews with program office personnel.

BACKGROUND

The MLRS is the result of studies begun in FY71 concerning battlefield scenarios of the 1980–90s. In particular, a need was identified for saturation artillery, a high volume of firepower in a short period of time. This need could best be filled by a rocket system, rather than the more common cannon artillery systems developed after World War II. In February 1974, a TRADOC Joint Working Group was established to assess the need for a General Support Rocket System (GSRS) with a counter-fire mission.[1] The Department of the Army approved a Letter of Agreement for development of a GSRS in September 1975. In March 1976, the Army's Missile Command (MICOM) Advanced Systems Office awarded five contracts for a four month GSRS concept definition phase to Boeing Aerospace, Emerson Electric, Martin Marietta, Northrop, and Vought. A provisional program office was established within MICOM in July 1976 and a draft DCP for GSRS was issued in November. At this point, the program was conceived as using a fairly conventional development approach. However, Congressional concern regarding the length of the acquisition cycle led the Army to accelerate the proposed schedule from about ten to bout seven years. The program schedule was later accelerated to about 5½ years. An ASARC I meeting in December 1976

[1]The MLRS was known as the General Support Rocket System until November 1979, when the name was changed. For our purposes here, the terms GSRS and MLRS are used interchangeably. The formal name change did not involve changes in design, requirements, or mission.

approved initiation of the GSRS program, though a formal development schedule and acquisition strategy were not approved at this time. DSARC I occurred in January 1977 and marked formal program initiation.

The MLRS program is managed by a project office in MICOM, a division of the Army's Materiel Command. The major users of the MLRS system are artillery units, mostly in Europe.

The MLRS is an unguided rocket artillery system "designed to supplement cannon weapons available to U.S. division and corps commanders for delivery of large quantities of firepower in very short time against time sensitive targets."[2] It is an all-weather rocket artillery system for indirect fire against field artillery, air defense systems, and light materiel/personnel targets and armor, especially in surge conditions. The MLRS consists of two basic subsystems. The SPLL is the carrier vehicle. It is a tracked vehicle and is a derivative of the M2/M3 Bradley Infantry Fighting Vehicle chassis developed by FMC. The chassis was provided to MLRS contractors in all phases of the program as government furnished equipment. The contractors modified the basic chassis to SPLL configuration. The rocket is unguided and is not a munition in itself. Rather, it is a carrier vehicle for various submunitions, including the baseline dual purpose conventional submunition for antiartillery and personnel missions, a scatterable mine (developed by West Germany) for antiarmor, and a more complex terminally guided warhead for antitank roles. The rockets are loaded, stored, and fired from pods, with each pod containing six rockets, and each SPLL carrying two pods. The rockets can be fired singly or in various ripple patterns. A crew of three can perform all firing tasks from within the SPLL cab and can reload the pods in about three minutes. The MLRS was envisioned as a state-of-the-art system using existing technology rather than pushing advanced technology.

ORIGINAL PLAN

The original acquisition plan approved at the January 1977 DSARC I was an accelerated strategy designed to reduce the time from program start to IOC. It included a 29 month competitive validation phase (beginning with contract award) in which two contractors would fabricate and test three prototypes each. A DT/OT I would occur at the end of this phase to examine the feasibility of the designs and the potential to satisfy requirements. An important decision point would

[2]Project Manager Charter, August 20, 1985.

follow this phase. If the prototypes reflected a satisfactory level of maturity and risk reduction during the validation phase, a single contractor would be chosen to move into a concurrent maturity/initial production phase. Under this strategy, the decision point would be a DSARC III, with contract awards the same month. This decision point was planned for May 1980. Initial production deliveries of the rocket and SPLL were scheduled for January and February 1982 respectively. A production qualification test would follow first delivery beginning in January 1982, with an OT III planned concurrently beginning in June 1982. A DSARC IIIa for full rate production approval was planned for November 1982, the same date as IOC.

If the prototypes did not show satisfactory maturity upon completion of the validation phase, the decision point scheduled for May 1980 would become a DSARC II. In this case, either one or both of the validation phase contractors would move into a more conventional FSD phase, lasting approximately two years, to be followed by a several month DT/OT II and award of initial production contracts. Though considerably less detail is available on these program alternatives, either one would have pushed IOC back by about two years.

The above discussion reflects a great deal of early planning in the MLRS program, with a substantial amount of acquisition strategy tailoring and allowance for contingencies. As it turned out, the prototypes did reach a satisfactory level of maturity and the first alternative was chosen, essentially eliminating an FSD phase. It is this plan that is the focus here.

A special ASARC in April 1977 approved the accelerated strategy with an early IOC. The competitive validation phase was detailed at this time, including the option to proceed into either a maturity/initial production phase or FSD depending on identified risks. NATO compatibility was also stressed, as were firm design-to-cost goals. The RFP released in April 1977 reflected this strategy and also provided the contractors with a great deal of design and tradeoff flexibility. The RFP gave basic concepts and objectives rather than detailed design specifications. The carrier vehicle and warhead fuze would be provided as government furnished equipment. Proposals were received in May 1977 and validation phase contracts (CPIF) were awarded in September to Boeing and Vought for $34.5 and $29.8 million respectively.

Competition and prototyping (the competitive validation phase) may have lengthened the MLRS program schedule. This would be true in the event that an FSD phase followed validation. It is generally believed that competitive prototyping lengthens a program schedule, but there is no unambiguous evidence to support this notion. However, if the FSD phase was eliminated, then the combination of the competitive prototyping phase and the concurrent maturity/initial production phase would together have contributed to shortening the schedule through concurrency and lack of separate contracting for development and production phases. External guidance from both Congress and the Army hierarchy also contributed to shortening the original plan.

EVENTS AND DEVIATIONS

Table J.1 presents the original plan for MLRS and subsequent changes for selected program milestones. The date under each revised plan column indicates when events affecting the schedule were recorded in program documentation. The original plan, measured from DSARC I to delivery of the first production SPLL, was 61 months.[3] The actual total program length was 67 months, a slip of only six months.

The original plan was modified slightly almost immediately. In January 1978, the Department of the Army directed that the MLRS include a scatterable mine submunition then being developed in West Germany. This entailed a minor redesign of the rocket to accommodate the new submunition. As a result, the validation phase was extended by three months, but the maturity phase was compressed to avoid slipping IOC. A new DCP was issued the same month reflecting these changes. This plan is used here as the MLRS original plan (see Table J.1), because details in downstream milestones for plans earlier than January 1978 are lacking.

The validation phase proceeded smoothly after this, with no further program restructures. Program requirements and the overall acquisition plan did not change as a result of the January 1978 directive; and Congressional, OSD, and Army support continued at a high level. This support is indicated by the small funding increases provided by Congress for the MLRS RDT&E account during the validation phase. For instance, Congress provided $5 million in FY77 instead of the $1 million requested to help accelerate the program.

In July 1979 the program formally became a multinational program, with the signing of a Memorandum of Understanding among the United States, U.K., France, and West Germany. Most of the multinational attributes of the program concerned submunition development and full rate production and so do not affect the portions of the program of concern here. DT/OT I began on schedule in November 1979

[3]The delivery of the first production SPLL, which was planned for after the first rocket pod delivery, marks the first date when a complete production unit (rocket and SPLL) would be available to operational units.

Table J.1

MLRS MILESTONE TABLE

Milestone	Original Plan[a] (May 79)	Revised Plan[b] (Apr 80)	Revised Plan[c] (Sep 80)	Revised Plan[d] (Mar 81)	Revised Plan[e] (Sep 81)	Revised Plan[f] (Mar 82)	Revised Plan[g] (Jun 82)	Revised Plan[h] (Sep 82)	Revised Plan[j] (Dec 82)	Revised Plan[k] (Dec 83)	Actual Date[m] (Dec 86)
DSARC I	Jan 77										Jan 77
Validation contract award	Sep 77										Sep 77
DT/OT I											
Start	Nov 79										Nov 79
Complete	Feb 80										Feb 80
DSARC III	May 80										May 80
Maturation contract award	May 80	Apr 80									Apr 80
Low rate production contract award	May 80	Apr 80									Apr 80
Initial production delivery											
Rocket	Jan 82				Mar 82	Apr 82	May 82				May 82
SPLL	Feb 82				Jul 82				Aug 82		Aug 82
Production qualification test											
Start	Jan 82				Apr 82		May 82				May 82
Complete	Sep 82				Feb 83						Feb 83
OT III											
Start	Jun 82			Jul 82	Oct 82						Oct 82
Complete	N/A			Sep 82	Jan 83					Mar 83	Mar 83
ASARC IIIa	N/A							May 83		N/A	
DSARC IIIa	Nov 82		Sep 82	Nov 82	Mar 83			N/A			
GOPR	N/A									Mar 83	Mar 83
IOC	Nov 82				Mar 83						May 83

[a]31 March 81 SAR (PE line); "MLRS Lessons Learned," July 80. The schedule in this column reflects the baseline plan for MLRS and is consistent with the 15 May 79 DCP for GSRS (previous name) supporting DSARC III. Original plan called for 29 months. Validation phase to be followed by a decision to go with single contractor/maturity/LRIP or into a more standard FSD phase (in which case DSARC III would be DSARC II). As the former was selected, the baseline for that option from the May 79 DCP is used as a proxy for the original plan. Also note that a January 78 program change directed by the Secretary of the Army to incorporate design changes to satisfy German requirements extended the validation phase by three months. This change is not reflected in the table because of lack of documentation for downstream milestones.

Table J.1—continued

[b]30 Jun 80 SAR: Maturity and low rate production contracts were awarded one month early after April 80 ASARC determined that maturity of validation phase prototypes warranted selection of this option.

[c]30 September 80 SAR: DSARC IIIa moved forward one month to agree with approved program at DSARC III contained in SDDM 7 August 80.

[d]31 March 81 SAR: Delay of one month in OT III start because of unavailability of test range. OT III completion date added to improve visibility. No reason for DSARC IIIa change found.

[e]30 September 81 SAR: International Association of Machinists and Aerospace Workers strike at FMC plant from 4 April 81 to 17 Jun 81. Work started again 22 June 81. Strike affected SPLL deliveries; rocket deliveries were deferred to be compatible with revised SPLL deliveries and PQT testing schedule.

[f]31 March 82 SAR: One month delay in first delivery of rocket because of minor problems in final assembly.

[g]30 June 82 SAR: Additional one month delay in first delivery of rocket pod because of minor assembly problems.

[h]30 September 82 SAR: Memo for Under Secretary of Army dated 16 April 82 gave Army management review authority.

[j]31 December 82 SAR: Initial SPLL delivery one month late because of production start-up problems.

[k]31 December 83 SAR: Last rounds of DT/OT III testing were fired in March 83. ASARC IIIa downgraded to a General Officer's Program Review that satisfied Milestone IIIa requirements.

[m]31 December 86 SAR: Actual dates of accomplishment. Note that beginning with December 85 SAR, Milestone IIIa events were labeled IIIb.

and was completed as planned in February 1980. An ASARC III occurred in April 1980 and approved entry into the maturity/initial production phase with one contractor. Prototype testing during the validation phase had shown that a satisfactory level of maturity had been attained and that risks had been sufficiently reduced to warrant continuation of the accelerated strategy. Vought received the maturity/initial production contract one month early in April 1980, and DSARC III occurred on schedule in May 1980.

Figure J.1 shows the evolution of the MLRS program schedule for selected milestones. The original plan is read off the horizontal axis, and subsequent plans are indicated by changes in the lines for the various milestones. The vertical axis gives the date when program changes occurred. The numbers on the figure give the months of slip for specific milestones associated with particular events. The reasons for the slip in first delivery are provided on the right, as well as the associated months of slip.

FY81 low rate initial production Option 1 was exercised in October 1980 for 2340 rockets and 32 SPLLs. The next program change occurred around March 1981: OT III start slipped one month (from June 82 to July 82) because no test range was available. Since the OT III milestone is downstream of first production delivery, no change to first delivery occurred, and IOC was also maintained at the original date of November 1982.

The most severe program restructure occurred around September 1981. The International Association of Machinists and Aerospace Workers went on strike at FMC (supplier of the SPLL to Vought as government furnished equipment) on April 4, 1981. The strike was settled on June 17 and work restarted on June 22. The strike affected the SPLL deliveries; rocket deliveries were deferred to be compatible with SPLL availability and the revised production qualification test schedule. As of September 1981, the revised program schedule indicated that first production delivery of the rocket was delayed two months (from January 82 to March 82) and first delivery of the SPLL slipped five months (from February 82 to July 82). Production qualification testing would start in April 1982 (a three month slip from January 82) and be complete in February 1983 (a four month slip from September 82). OT III start also slipped three months (from July 82 to October 82) and OT III completion, DSARC IIIa, and IOC all slipped four months (from September 82 to January 83, November 82 to March 83 respectively). This was by far the most important event affecting the pace of the MLRS program and it was outside the control of either government or contractor management.

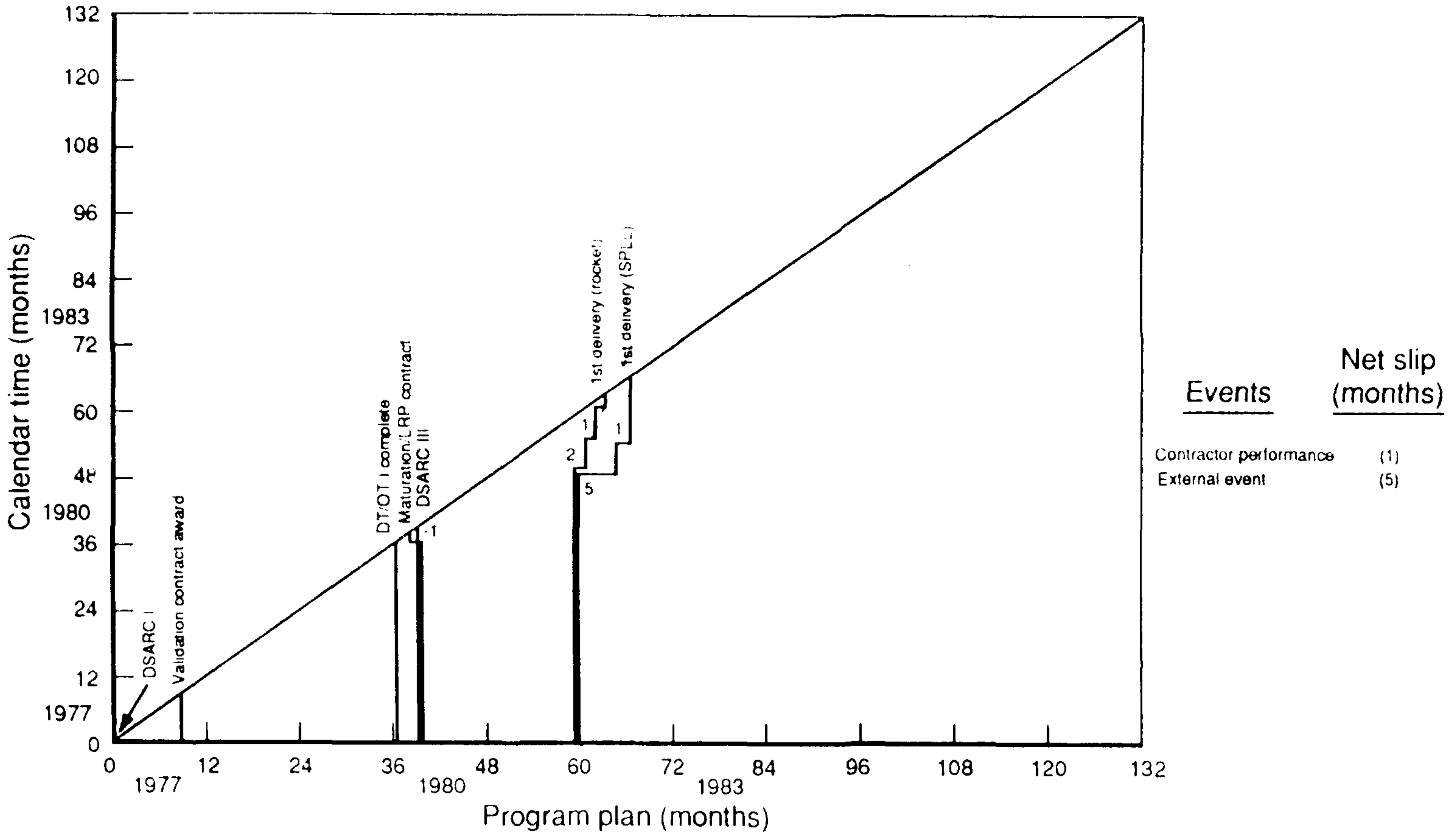

Fig. J.1—MLRS schedule evolution

The remainder of the program proceeded fairly smoothly. First delivery of the rocket pods occurred in May 82 (a slip of two months) because of problems in final rocket assembly. First delivery of the SPLL slipped one month (from July to August 82) because of production startup problems. All other milestones were met by the revised schedule dates. The DSARC IIIa decision for full rate production approval was delegated to the Army, and the Army's ASARC was downgraded to a General Officers Program Review (GOPR) soon thereafter. The GOPR and IOC both occurred in March 1983.

SUMMARY

Table J.2 presents a summary of the factors affecting the pace of the MLRS program. The total planned length of the program from DSARC I to first production delivery (SPLL) was 61 months. The total actual program length was 67 months, a deviation of only six months or about 10 percent of the original plan. The MLRS plan was highly accelerated, and the program succeeded in its goal of

Table J.2

FACTORS AFFECTING PACE—MLRS

	Original Plan	Deviation from Plan
Competition	L	
Concurrency	S	
Funding adequacy		
Prototype phase	L	
Separate contracting	S	
Service priority		
External guidance	S	
Joint management		
Program complexity		
Technical difficulty		
Concept stability		
Contractor performance		1 (Production startup problems)
External event		5 (IAM/AW strike)
Funding stability		
Major requirements stability		
Program manager turnover		
Total accounted for		6
Unknown		0
Total slip to first delivery		6

accelerating IOC. We have fully accounted for the six months of slip in first delivery.

Competition and prototyping (the competitive validation phase) may have lengthened the MLRS program schedule. This would be true in the event that an FSD phase followed validation. It is generally believed that competitive prototyping lengthens a program schedule, but there is no unambiguous evidence to support this notion. However, if the FSD phase was eliminated (as it eventually was), then competitive prototyping and the concurrent maturity/initial production phase would together have contributed to shortening the schedule through concurrency and lack of separate contracting for development and production phases. External guidance from both Congress and the Army hierarchy also contributed to shortening the original plan.

The strike at the FMC plant had the largest effect on the MLRS program schedule, accounting for five of the six months of slip in first production delivery. This is an external event, as neither government nor contractor managers had direct control over the situation. The other one month slip is categorized as contractor performance, because startup problems are often the result of poor production planning rather than technical difficulty.

The MLRS is often held up as a successful program: it came in with only a minimal schedule slip, and cost and performance goals were attained. Reasons for this success include steady Congressional, OSD, and Army support; adequate funding; reduced system complexity; strong management and planning from the beginning; and clearly stated and unchanged user requirements. The success of the program is probably due to all these factors working to reinforce each other.

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Appendix K

NAVSTAR GLOBAL POSITIONING SYSTEM

This appendix briefly summarizes the factors affecting the pace of the Navstar Global Positioning System (GPS), a space-based navigation and positioning system. Cost and performance are discussed only with respect to their effect on program schedule. Though GPS consists of three segments (space, ground control, and user equipment), this discussion focuses on the satellite portion only. The information contained here comes from various sources, including public literature, program documentation, and interviews with program office personnel.

BACKGROUND

The GPS program began as the Defense Navigation Satellite System (DNSS) in 1973. An April 1973 Deputy Secretary of Defense memorandum designated the Air Force as the lead agency to consolidate the various positioning/navigation systems into a single program. The DNSS concept was based on the best features of earlier Navy and Air Force programs. Since 1964, the Navy had been working on TIMATION, a space based navigation system technology program that incorporated two experimental satellites, the first of which was launched in May 1967. Concurrently, the Air Force was working on a similar technology program that resulted in a design concept called System 621B and included three segments: space, ground control, and user equipment. These programs were merged in 1973 and became DNSS.

The purpose behind the consolidation of navigation systems was to limit the proliferation of the many specialized navigation and positioning systems. This was expected to save money, particularly with respect to operation and maintenance costs. The user equipment would allow universal application across the services and possibly NATO. The particular need addressed by GPS was the ability to precisely position all friendly and adversarial forces in a common grid (the World Geodetic System Coordinates), support reconnaissance and intelligence missions, and provide 24-hour all-weather global coverage in an ECM environment at increased accuracy.

GPS is a joint program with the Air Force as lead agency. There are seven participating agencies, each with a deputy program manager: Air Force, Army, Navy, Marine Corps, NATO, the Defense Mapping Agency (DMA), and the Department of Transportation (DOT). DOT represents the civilian application of GPS, which is basically the same as the military but at reduced accuracy.

The space segment of GPS includes 24 satellites (original plan) in six different orbits at 20,200 kilometers, approximately 55 degree inclination, and a 12 hour period. Each satellite transmits position, velocity, and time data on two frequencies (1575.4 MHz and 1227.6 MHz). The most technically advanced aspect of the satellites is the atomic (cesium) clocks, which are fundamental to providing increased accuracy. The control segment consists of a master ground station to accumulate data and track the satellites, other widely spaced tracking stations, and several antennas to update the satellites. Each user needs four satellites within line of sight to accurately estimate position with a passive receiver.

The user equipment portion of GPS is the area where the joint nature of the program comes into play. There are three basic classes of user equipment: a one-channel manpack/vehicular receiver, a two-channel receiver for moderate speed vehicles (e.g., helicopters), and a five-channel receiver for high speed aircraft and Navy ships.

ORIGINAL PLAN

Milestone I took place in December 1973 and approved entry into a concept validation phase. At that time, Milestone II was set for March 1978 and IOC for 1984. The Phase I program was to include the launching of four satellites: NTS-2 from the Navy's previous program, and three Navigation Development Satellites (NDS). NDS-3 was originally planned for launch in July 1977. These first satellites were intended as prototypes to validate design and satellite configuration concepts. A contract was awarded to Rockwell International for four satellites (one ground test and three prototypes) in June 1974. User equipment and control segment contracts were also awarded about that time. While neither the space nor control segments were competitive after concept validation contract award, the user equipment segment was planned to be fully competitive through Phase II (FSD).

The technical objectives of Phase I were to confirm the concept of a space based navigation system and establish the preferred design. Operational objectives included defining the military value and system cost. Both sets of objectives were spelled out in some detail in the original Decision Coordinating Paper (DCP) and Program Management Directive (PMD). Other objectives during Phase I included the determination of phase-out timing and costs of existing systems that GPS would eventually replace, and testing new operational concepts. Other than increased accuracy, the "essential" requirements for DNSS/GPS were:[1]

- Worldwide coverage.
- Passive operation.
- Deny use to unfriendly forces.
- No user saturation limit.
- ECM resistance.
- Positioning data in real time.
- 3-D capability.
- Common coordinate reference and user equipment.
- Accuracy insensitive to altitude or high energy maneuvers.
- Continuous availability.

In essence, Phase I was planned as a true concept validation phase using hardware to demonstrate and refine system concepts and operational utility.

The three alternatives examined in the DCP supporting DSARC I all envisioned IOC in 1984. The differences were in the costs and specific activities of Phase I. In particular, reducing certain activities (e.g., the number and payloads of the satellites) increased risks associated with validating technical and operational objectives. The alternative chosen (Alternative III) was the highest cost and lowest risk alternative and included a competitive user equipment segment. Phase I seems to have concentrated on the space segment, with more focused development and testing of user equipment deferred until Phase II.

The reasons why the DNSS/GPS original plan looked the way it did are not clear. The plan appears to allow a reasonable amount of time for testing in support of DSARC II. The joint nature of the prog..., the incorporation of prototypes, and the lack of concurrency all seem to contribute to the planned schedule. Joint programs are often lower priority programs relative to the specialized programs in each service supporting service missions. Both joint management and low service priority tend to lengthen plan schedules. In addition, the intangible nature of the concept and its newness imply that extra selling efforts were required to establish the program. In fact, the original program was funded at about $100 million, just enough to cover the satellites

[1]Decision Coordinating Paper, "Defense Navigation Satellite Development Program," 21 June 1973.

but not enough for the other elements of Phase I. This funding was apparently used to cover the entire program until additional funding became available from other sources (program elements in the budgeting process). Program complexity, allowing for the numerous external interactions surrounding GPS, also appears to have lengthened the plan.

EVENTS AND DEVIATIONS

Table K.1 presents the original program schedule for GPS and subsequent program changes for selected program milestones. The date under each revised plan entry is the date of the document from which the program change was taken. The main data sources for Table K.1 are the *Selected Acquisition Reports* for GPS. These data were validated or supplemented from other sources when appropriate.

Phase I

The concept validation phase, which ran from DSARC I in December 1973 to DSARC II in June 1979, appears to have been fairly smooth, despite several program changes. For instance, the nuclear detonation detection mission was added to the satellite payload early in the program, and planning for operational satellite launches on the Space Shuttle also commenced during Phase I. The first satellites were changed to more closely resemble operational satellites, with more of the design parameters set before fabrication. Further, in August 1974, the program office was directed to procure four additional NDSs to support the Navy's SLBM Improved Accuracy Program (IAP). Procurement of these satellites was amended to the existing contract with Rockwell in November 1974 (NDS-5 and 6) and again in August 1976 (NDS-7 and 8, replenishment satellites). The Navy required a six satellite constellation in support of the IAP. By the end of Phase I all objectives had been met. Eight NDS satellites and NTS-2 were developed and purchased, and NTS-2 and NDS-1 through 4 had been launched on Atlas launch vehicles.

Late in 1976, several funding problems combined to delay the launching of the first set of development satellites planned for 1977. FY77 funding needs were higher than predicted by the JPO, the Atlas launch vehicle required higher funding, and ground control and user equipment contracts required higher funding for FY77 and FY78.[2] This resulted in

[2] *The A3 Data Handbook*, TASC, November 15, 1982.

Table K.1

NAVSTAR GPS MILESTONE TABLE

Milestone	Original Plan[a] (May 74)	Revised Plan[b] (Jun 78)	Revised Plan[c] (Dec 80)	Revised Plan[d] (Sep 81)	Revised Plan[e] (Dec 81)	Revised Plan[f] (Mar 82)	Revised Plan[g] (Jun 82)	Revised Plan[h] (Dec 82)	Revised Plan[j] (Dec 83)	Revised Plan[k] (Dec 84)	Revised Plan[m] (Jun 85)	Revised Plan[n] ((Dec 85)	Revised Plan[p] (Sep 86)	Actual Date[q] (86/87)
DSARC I	Dec 73		Dec 73											Dec 73
DSARC II	Mar 78	Feb 79	Jun 79											Jun 79
Space segment														
System design revision			Jan 80											Jan 80
Preliminary design revision			Mar 80											Mar 80
Replenishment satellite contract award			Oct 79											Oct 79
Block satellite contract award			Dec 80											Dec 80
Satellite production contract			Jan 82	Apr 82		Jun 82	Aug 82	Sep 82						Sep 82
1st launch ready satellite			Apr 85				Dec 85	May 86	Aug 86				Jan 87	May 87
1st production satellite launch													Jan 89	Oct 88
Control segment														
Development contract			Sep 80											Sep 80
Operational control segment (FOC)			Nov 87											Apr 91 est
User segment														
Phase IIB FSED contract			Jul 79											Jul 79
Begin DT&E/IOT&E			Jan 83		Jun 83		Sep 83		Aug 84					Aug 84
Complete DT&E/IOT&E			Oct 83		Feb 84		Sep 84		Dec 84	Jul 85	Dec 85	May 86		May 86
Source selection			--							Apr 85				Apr 85
Phase III PDR			--									Dec 85		Dec 85
Production contract			Jan 84		Jul 84				Jan 85	Mar 86		May 86	Aug 86	Aug 86
Phase III CDR			--										Dec 86	Dec 86
Program														
JRMB IIIa	Jan 82		Sep 83		May 84				Jan 85	Oct 85	Feb 86	May 86	Jun 86	Jun 86
3-D Capability	Aug 84		Dec 87		Sep 88		Dec 88						Mar 31	Nov 90 est
JRMB IIIb		Aug 82	--									Mar 89		Sep 89 est

[a]PMDs 2 May 74 and 7 July 75: The July 75 PMD is the first with detail schedule for whole program. Contract details not included. The only other change between this scheule and the next was 3-D capability in January 85 (FOC) in the 11 November 76 PMD. No reasons for change given.

[b]15 June 78 PMD. 3-D capability was deferred until 2QFY86 for initial and 2QFY87 for FOC.

Table K.1—continued

[c]31 December 80 SAR (DE line) (looks like first SAR). This appears to be the same basic schedule in more detail that appears in 21 June 73 DCP. DSARCs I and II are the same. DSARC III was planned for mid-1981. DSARC III - JRMB IIIa. Some documents indicate November 84 as original IOC date for GPS.

There was a major program restructure before this SAR because of December 79 OSD funding cut. Scope of the program reduced. (See "event line.")

[d]30 September 81 SAR (CE line): January 82 contract award based on old annual buy strategy. New April 82 date based on 28 satellite block buy strategy.

[e]31 December 81 SAR (CE line): Delay of IOT&E start and completion due to UE contractor schedule slip. UE production contract slip due to same. DSARC III also due to UE contractor slip. September 81 OSD 3020 satellite funding reallocation slipped FOC.

[f]31 March 82 SAR (CE line): Satellite production contract slipped due to new block buy strategy. Contract award delayed due to requirement for prior notification of Congressional reprogramming action.

[g]30 June 82 SAR (CE line): Contract award delayed due to Congressional reprogramming action. Delay of 1st shuttle launch (production ready) due to slip in contract award date. Delay of IOT&E due to contractor slip, new contractual joint test and integration, and realignment of test vehicles and schedule to accommodate contractor slip.

[h]31 December 82 SAR (CE line): Satellite contract slip due to Congressional delay in reprogramming action. Shuttle launch slip due to program slip.

[j]31 December 83 SAR (AP/CE line): Changes included in FY85 President's Budget. Delays in UE milestones due to technical problems with receiver processor software/hardware encountered during testing, correction of problems, and late delivery of antenna units by subcontractor.

[k]31 December 84 SAR (CE line): AF and N will complete DT&E/IOT&E in July 85 with the Army continuing until December 85. Final integration of UE into host vehicles and maturing the system was underestimated. This is the first time that the Source Selection milestone has appeared in an SAR. Delay of the UE production contract was due to compliance with PL 9894. DSARC III is now DSARC IIIa LRIP decision per PL 9894--has been delayed for above reasons.

[m]30 June 85 SAR (CE line): Problems encountered with UE development have slipped completion of testing. Army retesting will not provide sufficient information to support a Tri-service DSARC IIIa decision until February 86.

[n]31 December 85 SAR (CE line): Reliability and Maintainability problems identified during Phase II dictated additional testing. These R&M problems caused DSARC IIIa and production contract award dates to slip. DSARC IIIb added to comply with PL 9894.

[p]30 September 86 SAR (CE line): Delivery of 1st Block II satellite delayed due to minor production problems associated with 1st satellite going thru production process. JRMB IIIa delayed due to continuing negotiations to include reliability improvement programs in production contract. Subsequently, production contract and CDR slipped. Launch of 1st satellite slipped due to shuttle standown. This slipped 3-D capability.

[q]31 December 86 SAR (CE line) and February 87 PMD: Estimated dates are indicated. 3-D capability was estimated for March 91, and Milestone IIIB (full rate production for user equipment) was estimated for March 89.

30 June 87 SAR (CE line): Navstar #13 (first production satellite) was not launch ready as planned due to delays associated with the launch manifest restructure and a slip in the contract award date. First production satellite launch is three months earlier than planned in the December 86 SAR due to contract award for the Delta II launch vehicle. 3-D capability is five months earlier than December 86 plan also due to Delta II contract. Milestone IIIB decision slipped from March 89 to September 89 to allow additional user equipment testing.

partial stop-work orders being issued. NTS-2 was launched in June 1977 and NDS-1 was launched February 1978, both nine months after their launch dates in the original plan. NDS-4 was launched December 1978, only a slight deviation (about one month) from the original plan. DSARC II was delayed in part to allow additional testing to support the FSD test (from March 78 to February 79) and then again because of the extensive briefing process (60 pre-DSARC briefings) in preparation for DSARC II. At least one month of this is attributable to the problem of aligning the schedules of the DSARC participants. Measuring from DSARC I to DSARC II, the total deviation in the program was 15 months. However, all Phase I objectives were met.

Phase II

The major focus of Phase II (full scale development) appears to have been on user equipment development. In terms of the space segment, the objectives were to maintain a six satellite constellation in support of the Navy's IAP program, and plan for satellite production.

A December 1979 OSD decision cut $500 million (approximately 30 percent) from the budget over the period FY81–FY86. This caused a major program restructure which was approved in March 1980.[3] The final satellite constellation was reduced from 24 to 18 satellites, with three on-orbit spares, Block 2 development satellites were dropped, and the design was scaled down in terms of weight, power, and nuclear and laser hardening. Attainment of an early limited 2-D capability in 1981 was also dropped. This major restructure did not seem to affect any of the space segment milestones.

The DSARC II decision to enter full scale development, approved in August 1979, seems to also have been an authorization to proceed with satellite production. Though there was originally a DSARC III for the satellite scheduled for 1981, this meeting appears not to have occurred. In fact, the Block 2 satellites (production configuration) do not differ substantially from the last NDS design. The major differences include improved batteries and solar cells to increase the design life of the satellites from 5 to 7.5 years, addition of a cross-link transponder for communication with other satellites, additional hardening features, and digital (vs. analog) attitude control.[4] The major technical challenge for the satellites seems to have been the reliability of the cesium clocks, a problem that was mostly corrected by the time the satellite production

[3]Memorandum for the Secretary of Defense from Secretary of the Air Force Hans Mark, 4 March 1980.

[4]*Aviation Week & Space Technology*, September 8, 1986.

contract was awarded. It has been suggested that satellite production could have commenced immediately after DSARC II in 1979. A lack of funding caused additional satellites to be procured one at a time beyond NDS-8, the last satellite contracted for in Phase I. Award of the production contract seems to have incurred substantial slips, which affected the delivery of the first production unit (GPS-13).[5]

Figure K.1 provides the evolution of the schedule for selected program and space segment milestones. The original plan is read on the horizontal axis and subsequent schedule changes are reflected in the various curves for each milestone. The vertical axis gives the date when the change appeared in program documentation. Each number represents months of slip in a milestone. The first documented date for satellite production contract award was January 1982. Before that, in early 1981, the satellite procurement strategy was revised from annual contract awards to a fixed price, multi-year block buy strategy (28 satellites on the first contract over a five year period). This strategy revision, along with a requirement to notify Congress of reprogramming actions and receive approval, slipped the award date eight months to September 1982. There are indications that the contract negotiation process took considerably longer than this slip indicates—more than 18 months.

The delivery of the first production unit (GPS-13) was delayed eight months from April 1985 to December 1985 because of the slip in contract award. Additional delays were incurred because of the reprogramming action (five months to May 86), continued contract negotiations under constraints in the FY85 budget that established August 1986 as the earliest delivery date, technical problems associated with the first satellite going through the production line (GPS-12, the qualification vehicle: five months to January 1987), and a further delay due to the launch manifest restructure associated with the Challenger accident (to May 1987). This last item is important. GPS depends on external programs to achieve IOC. The shuttle was the only planned launch vehicle for production satellites. The Challenger accident caused a 24 month launch standdown. The pace of production was slowed, reflecting the necessity to re-plan the launch schedule and bring another launch vehicle (in this case, the Delta II) on line.

Despite our expectation that Milestone IIIA was a low rate production decision for the total program, it was in fact only related to the user equipment segment. Delays in this milestone reflect the availability of user equipment to support an IOC date, thus affecting the pace

[5]At this point in the program, the real driver of program pace was the user equipment segment. Though we did not examine this segment in detail, future consideration of factors affecting the pace of GPS should look at the user equipment segment in detail.

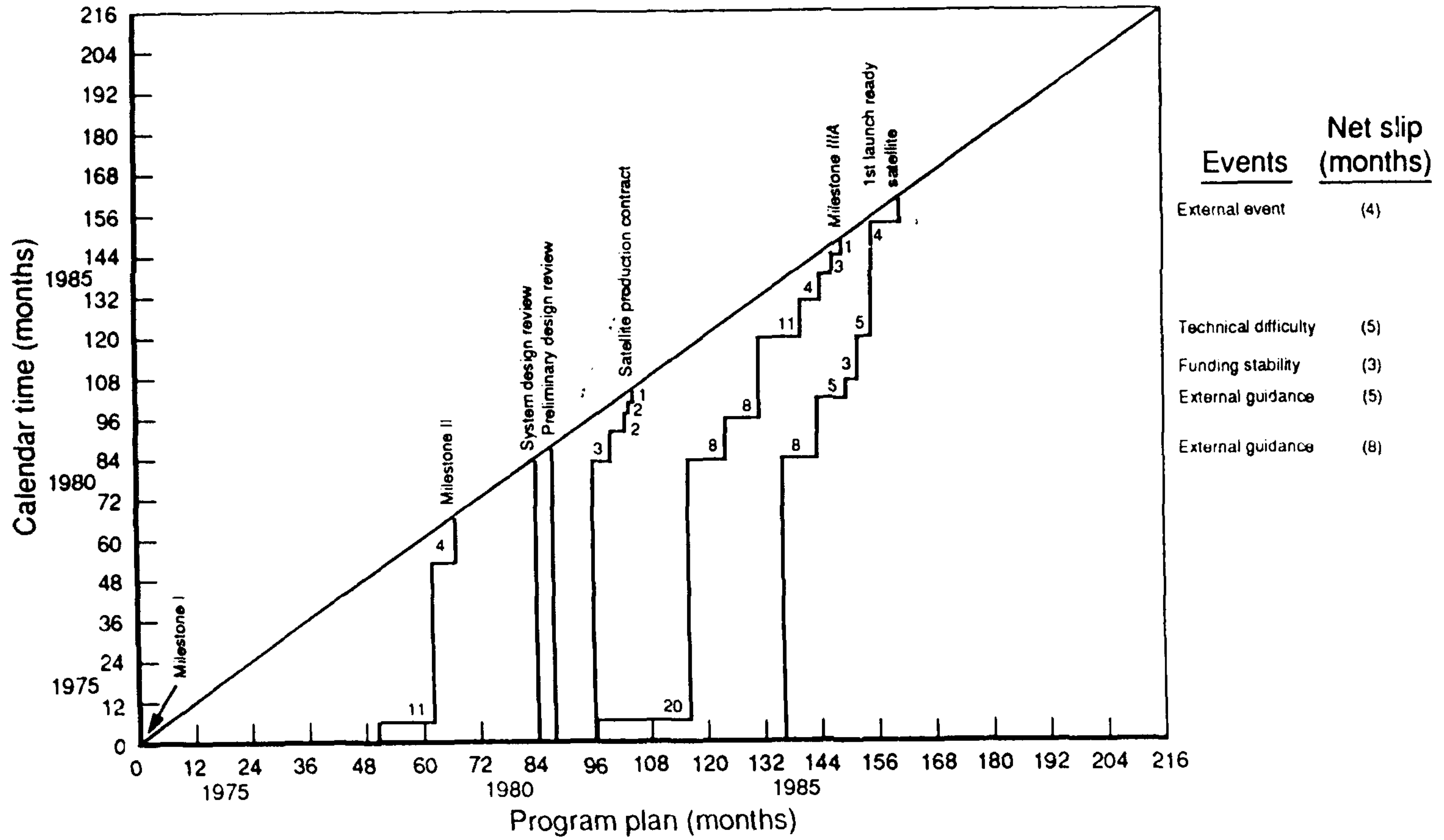

Fig. K.1—Navstar GPS schedule evolution

of the satellite segment, which was slowed in the absence of deployable user equipment. Reasons for slips in this milestone include the major program restructure (approximately 20 months from January 1982 to September 1983), contractor technical problems (eight months to May 1984), contractor integration problems and late delivery of the antenna by a subcontractor (eight months to January 1985), compliance with PL 9894 and technical problems regarding reliability (11 months to February 1986), additional reliability problems delaying completion of IOT&E (four months to May 1986) and contract negotiations to include reliability improvements in the user equipment (one month to June 1986). It is notable that 110 briefings were required to pass the Milestone IIIA point, a good indication of the management complexity of a joint program.

SUMMARY

Table K.2 presents the summary of factors affecting the pace of the GPS space segment. Most of these factors have been previously

Table K.2

FACTORS AFFECTING PACE—NAVSTAR GPS

	Original Plan	Deviation from Plan
Competition		
Concurrency		
Funding adequacy		
Prototype phase		
Separate contracting		
Service priority	L	
External guidance		8 (block buy/reprogramming) 5 (Congressional approval)
Joint management	L	
Program complexity	L	
Technical difficulty		5 (first production run)
Concept stability		
Contractor performance		
External event		4 (launch restructure)
Funding stability		3 (contract renegotiations)
Major requirements stability		
Program manager turnover		
Total accounted for		25
Unknown		0
Total slip to first delivery		25

discussed. We believe that we have accounted for the entire deviation from the original plan, measured from DSARC I in December 1973 to first production satellite delivery in May 1987, a total program length of 161 months.

The joint nature of the program seems to have had a strong influence on the original plan, through both service priority and funding adequacy. A joint program increases the need to sell a program. A short schedule enhances the ability to sell it. In this case, the program seems to have had good support in OSD and needed to be sold to the services. Both the joint management nature and the low priority of the program in the participating services seem to have lengthened the original plan.

The complexity of program management also seems to have affected the GPS original plan. In particular, GPS has many external interactions, particularly in the area of integrating the user equipment into the various weapon systems, but also in terms of the launch vehicle. The schedule must reflect this to some extent.

Other factors affecting the original plan are less clear. The original plan certainly reflects the incorporation of a prototype phase, separate contracting across both segments and phases, and the lack of concurrency. However, in no case were we able to allocate portions of the program schedule to particular factors.

The GPS program slipped 25 months in the first production satellite delivery, or about 18 percent of the total length of the original plan. The major factors are listed in Fig. K.2 and were discussed previously. Most of these deviations were beyond the control of program management, except perhaps the initiation of the block buy strategy.

Several other aspects of the GPS program did not measurably affect program pace. The GPS funding base is very broad, covering many different program elements. This acted as a discouragement to external direction: Making a program change in one element would affect all other aspects of the program. GPS is not a standard weapon system with a well-defined mission and a long history of operational concepts. Rather, it is a support system, the value of which is less straightforward than that of tanks or aircraft. As stated previously, this increases the need to sell the program, particularly to users. The GPS program office addressed this problem, especially during Phase I, by emphasizing one of the more tangible capabilities of the system: increased bombing accuracy. As a joint program, GPS had service support difficulties. For instance, the program was zeroed out in the first three years after DSARC II but was reinstated by OSD. OSD support seems to have contributed to the survival of the program. In particular, Assistant Secretary Donald Latham (C^3I) was an avid supporter.

When asked if the program could have been accelerated, program office personnel answered that in the absence of external influences, the user equipment segment could perhaps have been accelerated by 12 months, though the space segment would have remained the same in Phase I. Assuming availability of user equipment, and given that satellite production could have started immediately after DSARC II, the total program could have been accelerated by only about 12 months, or about 7 percent of actual total program length.

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